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Studies on Marine Deposits

I. On the Action of Sea-salts upon the Sedimentation of Fine Mud[1]

By

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With 15 Text-figures and 12 Tables

I. Introduction

The distribution on the sea bottom of mud sediment transported by rivers is a matter of great importance in oceanography and geology. To ascertain the manner in which the sedimentation occurs, it is not sufficient to have only a knowledge of dynamical nature such as the distribution of water current in the estuary and the law[2] relating to the size of mud particles which the current can suspend mechanically, but we must also undertake physico-chemical studies on problems such as the accelerating action of sea-salts upon the sedimentation of fine mud.

The fact that the suspensoids in general are easily coagulated by the addition of a minute quantity of salt has been known from early times. According to Weule,[3] in 1837/38 Sidell had already noticed that muddy water taken from the Mississippi and left undisturbed required several days to become clear, while with the addition of salts it completely precipitated within a few hours. With the subsequent development of colloid-chemistry, the coagulating effect of salts on various coloidal solutions was investigated. Notwithstanding these studies, except Bodländer's investigation[4] of kaolin-suspensions, data useful for treating the sedimentation of mud in sea water are very few.

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1) The outline of this paper was read before the meeting of the National Committee of Japan on Pacific Oceanography on Dec. 21, 1929.

2) cf. H. E. Hurst: The Suspension of Sand in Water, Proc. Roy. Soc. London, A, Vol. 124 (1929), p. 196.

3) Ann. d. Hydrog. u. Mar. Meteor. Vol. 24 (1910), p. 402.

4) Nachr. d. Gött. Ges. d. Wiss. 267 (1893).

The turbidity of river water, the distribution of salinity and the rate of current adjacent to the estuary are easily measured. It will be, therefore, very desirable to find some method which enables us to estimate from these three series of observations, the rate of mud-sedimentation on various parts of the sea-bottom. And for this purpose, we must have preparatorily made experimental investigations not only on the dynamic action of water-currents but also on the physico-chemical effect of sea-salts upon the sedimentation of mud such as:

(1) The rate of mud-sedimentation according to the salinity of sea-water, and

(2) The rate of mud-sedimentation according to the initial turbidity of mud water.

Now, ocean water has an average salinity of 35‰, and the Dittmar's analysis[1] shows that the principal components are as follows:

Substance	gr per litre of water	Normality of cation
NaCl	27.213	1/2.16 n of $Na^{\cdot}$
$MgCl_2$	3.807	1/18.5 n of $Mg^{\cdot\cdot}$
$MgSO_4$	1.658	
$MgBr_2$	0.076	
$CaSO_4$	1.260	1/95.4 n of $Ca^{\cdot\cdot}$
$CaCO_3$	0.123	
K_2SO_4	0.863	1/78.3 n of $K^{\cdot}$
Total	35.000	

Of course, the various seas vary considerably in their degree of salinity, especially along the continental coasts, but it is a characteristic of the composition of all sea-waters that the ratios between each of its elements are almost constant and that those values are the same as in the above table. It is also a well known fact that suspended particles in so-called suspensions are in general negatively charged and that the rapid coagulation by salts is due to the fact that the charges are neutralized by the attached cations and the flocking of the particles becomes much easier. Hence it is evident that the effect of sea-salts upon the sedimentation of mud is mainly due to the actions of $Na^{\cdot}$,

1) Challenger Reports: Physics and Chemistry I, p. 189.

$Mg^{\cdot\cdot}$, $Ca^{\cdot\cdot}$, $K^{\cdot}$; but if so, we must determine the relative efficiency of these ions, or in other words;

(3) The individual action of each element of the sea-salts upon the mud-sedimentation, and their relative importance.

In order to attain the above objects (1), (2), (3), we performed the following experiments.

II. Experiment

1. Samples of Mud

We used the following four samples of mud:

1) Grayish clay used for the Kiyomidu-ware, Kyoto.
2) Pure white kaolin from Korea.
3) Red clay obtained by washing the alluvium at Tanaka in Kyoto.
4) Muddy water from a branch of the rivulet Sirakawa, Kyoto, after a heavy rain.

As for the samples 1, 2 and 3, we first dried and then further pulverized them in a mortar. Next we sifted only the finest particles of mud through a sieve of 0.05 mm meshes. About 5 grs of the fine mud thus obtained was dissolved in a definite quantity of water, and left for one or two days. This period was required to saturate the dried mud with water uniformly. If sufficient time were not allowed for thorough saturation to take place, even though all the other conditions were the same, there might have resulted difference in the velocity of mud-sedimentation by the salts, with a constant lack of unity in our present experiments.

Now, the prepared mud-water was mixed with pure water or aqueous salt-solution of a definite concentration, so as to make both the quantities of mud and the concentration of salt as we desired. As soon as the mixing was done, the mixture was vigorously shaken and a part of it was put into a receiver for testing the variation of its turbidity.

To measure the variation of turbidity we used one or the other of the following two methods, depending upon the circumstances.

2. Method of Experiment

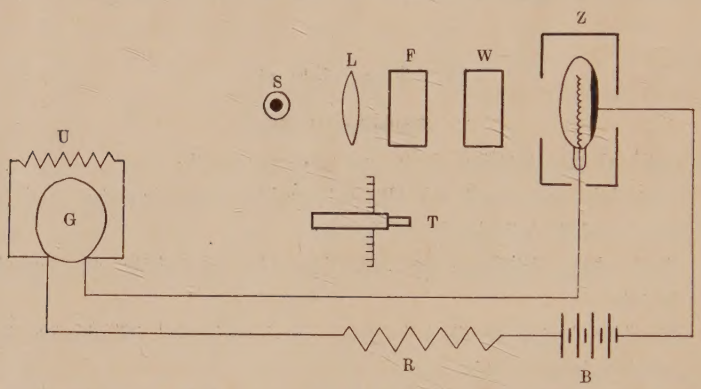
A) The first method with photo-electric cell

Formerly, the process of coagulation of a colloid was generally

observed by measuring the variation in its viscosity, but recently some investigators[1] on rare occasions have used photo-cells.

For our first test, we used a photo-cell to observe the decrease of turbidity with the lapse of time. The arrangement was as in Fig. 1.

Fig. 1. Arrangement for Experiment A.



S: a light source, which is a 200 watt lamp lighted with secondary batteries, the terminal voltage being carefully kept constant with a volt-meter and a rheostat.

L: a condensing lens.

F: a filter which absorbs heat rays to avoid convectional disturbance in the mud-water.

W: a vessel of mud water, which has two parallel walls of very thin glass and with an interspace of 1.5 cm. Light radiates upon a circular region with a diameter of about 3 cm whose centre lies 4.5 cm below the upper level of the water.

Z: a kalium photoelectric cell. Its front window is a circle with a diametre of 2 cm, and is opened for only a few seconds at the time of measurement.

G: an aperiodic galvanometer with a sensibility of 10^{-11} amp.

T: a reading telescope.

B: a 45 volt dry battery.

R: a resistance of ca. 100000 ohms.

U: A shunt resistance.

Before beginning our experiments with this apparatus, we had to complete the standardization of our photo-cell system. After a definite quantity of mud was mixed with various volumes of pure water, they were put into the receiver W in succession. Illuminating by a constant light, the corresponding deflection of the galvanometer was read. By

1) Lottermoser, Kolloidzeits. Bd. 15 (1914), 145.
N. N. Kalitin, Ann. d. Hyd. u. Mar. Met., 1925, s. 326.

means of such observations, a relation between the deflection of galvanometer and the turbidity of water was determined, and represented on a graph. Since very fine mud in pure water shows scarcely any sedimentation during the short time of a few seconds, the above standardization can be operated easily with a sufficiently satisfactory result.

After this standardization of the apparatus, mud waters including various quantities of salts and mud were tested, and at suitable time intervals the corresponding deflections of the galvanometer were read. Then comparing those readings with the standardization curve, we could determine exactly how the sedimentation of mud proceeds with the lapse of time.

B) The second method with test tubes

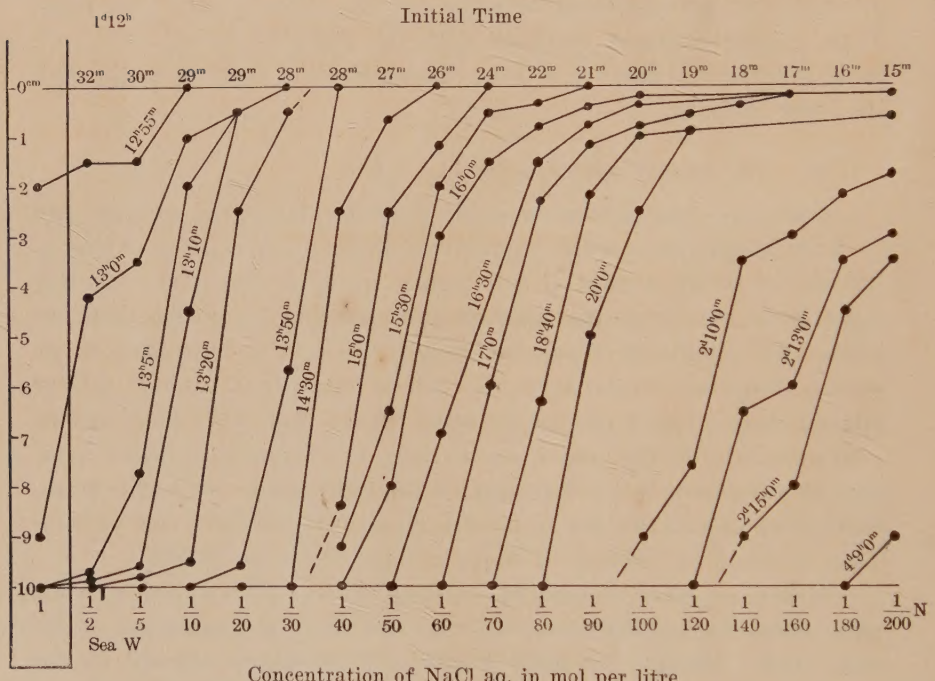
Using the first method, a single experiment requires at least two or three hours, even when coagulation takes place rapidly, while in the case of slight salinity, it will require up to several days. Accordingly, if we would use that method of experiment for all the different kinds and quantities of salt and mud, it would be necessary to do several hundred experiments in succession, which would be too labourious and would require too much time. Moreover, when experiments extend over too long a period, there arise many sources of error, such as variations in the intensity of the light source, or in the sensibility of the photo-cell due to the decaying of its auxiliary dry battery. Thus it would be difficult to secure results worth our labour.

Hence we were obliged to consider other methods which, while more primitive, permit numerous experiments to be performed at the same time. Finally, we made a series of experiments based on the principle of the Secchi disc which is used for measuring the transparency of the open sea: we took special test-tubes (diameter 3 cm, length 20 cm) as uniform as possible, and along one side of each tube pasted a scale visible from the other side. Into each of several dozens of these tubes we put a quantity of mud water of different salinity and turbidity respectively. At first the scale on any tube was not visible from the other side due to the muddiness of the water; but as time lapsed and mud-sedimentation advanced, the scale began to become visible gradually from the upper part to the lower. At suitable intervals, we read the lowest position of the visible part of the scale on each tube. Thus we were able to study how the sedimentation in

each tube advanced with the lapse of time and how the difference of initial turbidity and of salinity affected the sedimentation.

As an example, the observations on the effect of $Na^{\cdot}$ concentration is shown in Fig. 2.

Fig. 2. An experiment with test tubes containing an initial turbidity 1.3 gr in L. The time notations along the curves show the time when that portion of the scale became visible.



Concentration of NaCl aq. in mol per litre

Now, what is the degree of turbidity at which the scale is just visible from the other side of our tube?

Its approximate value can be known by comparing the experiments of equal salinity and turbidity made using both the first and the second method. That is, we have only to observe in the photo-cell experiment, how the sedimentation advanced and how much the residual turbidity was at the time that the scale began to be seen from the other side in the test-tube experiment.

Next, to determine the exact value of the turbidity required, we prepared a number of test-tubes containing mud-water of no salinity,

but of different turbidities, each of which was near the approximate value above obtained but differing a little from one another. Of these tubes, the turbidity of one, in which the scale was just visible from the other side of the tube, will give the value to be required. In this way, we determined that the quantity of mud that enables the scales on our test-tubes to be seen from the other side is about 1.15 grs in litre for the mud of sample 1.

One might wonder, why was such an arbitrary intermediate turbidity taken as the standard for observation? Or, why was not the time up to the complete transparency observed? We did seek to observe the time up to the complete transparency, but on practice found that it was very difficult to distinguish when the complete transparency was just attained, which, if forcibly done, would contain a very large error. Thus we abandoned this method.

3. *Result of the Experiments*

A) Experiments by the first method

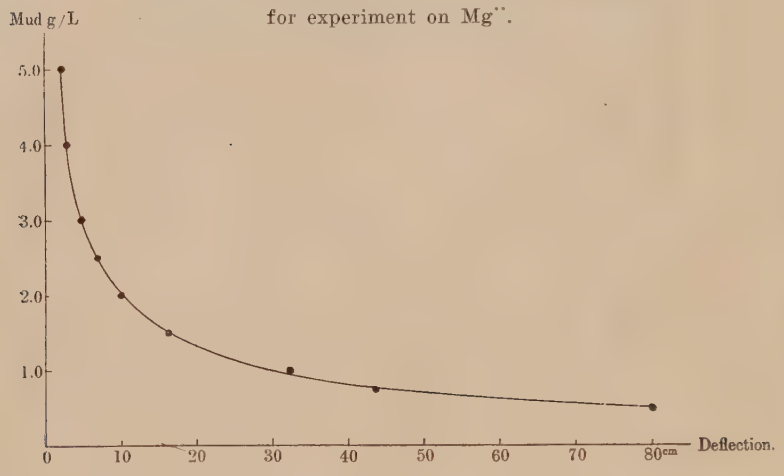
Five experiments were performed according to this method: in one case with water containing no salts and in four with aqueous solutions of $Na^{\cdot}$, $Mg^{\cdot\cdot}$, $Ca^{\cdot\cdot}$ and $K^{\cdot}$ respectively with concentrations identical with those in normal sea water, the turbidity being ca. 5 gr mud per litre in all cases.

The standardization of the photo-cell system was made prior to each experiment, but we include herein only one corresponding to exp. (i) for $Mg^{\cdot\cdot}$, as Table 1 and Fig. 3.

Table 1. Standardization of galvanometer before experiment on $Mg^{\cdot\cdot}$.

Mud (g/L)	Galv. deflection (cm)
5.0	2.0
4.0	2.8
3.0	4.8
2.5	6.9
2.0	10.0
1.5	16.2
1.0	32.5
0.75	43.5
0.5	80.0

Fig. 3. Standardization curve of galvanometer for experiment on $Mg^{..}$.



The results of all our experiments by the first method are shown in Table 2 to 6 and Fig. 4 to 8.

Table 2. Effect of $Na^{.}$.

Time	(1)		(2)		Mean of (1) (2)	
	Defl.	Mud	Defl.	Mud	Observed	Calculated
min	cm	g/L	cm	g/L	g/L	g/L
0	—	—	—	—	—	—
2	3.6	3.63	4.4	3.35	3.49	3.88
4	4.7	3.13	5.7	2.90	3.02	3.19
6	5.8	2.75	6.7	2.62	2.69	2.70
8	7.3	2.38	8.4	2.26	2.32	2.34
10	8.4	2.18	10.2	1.98	2.08	2.06
13	11.6	1.80	12.7	1.72	1.76	1.76
16	15.1	1.52	15.7	1.52	1.52	1.53
19	18.2	1.35	20.8	1.27	1.31	1.35
22	22.0	1.22	25.3	1.13	1.18	1.21
25	26.7	1.08	30.2	1.02	1.05	1.10
30	33.5	1.00	36.3	0.92	0.96	0.95
35	40.0	0.84	42.3	0.79	0.82	0.84
40	45.1	0.74	47.1	0.74	0.74	0.75
45	47.6	0.73	52.2	0.70	0.72	0.73
50	51.4	0.71	55.2	0.68	0.69	0.70
55	54.0	0.68	60.3	0.64	0.66	0.68
60	57.0	0.66	63.4	0.62	0.64	0.65
65	59.7	0.65	66.7	0.59	0.62	0.63
70	63.0	0.63	70.1	0.56	0.59	0.60
75	65.2	0.62	72.5	0.55	0.58	0.59
80	68.1	0.60	75.0	0.53	0.56	0.57
85	70.5	0.58	76.8	0.52	0.55	0.55
90	72.5	0.57	78.6	0.50	0.54	0.54
100	77.0	0.54	84.3	0.47	0.50	0.50
110	80.2	0.52	87.0	0.44	0.48	0.48
120	83.2	0.50	91.5	0.40	0.45	0.46

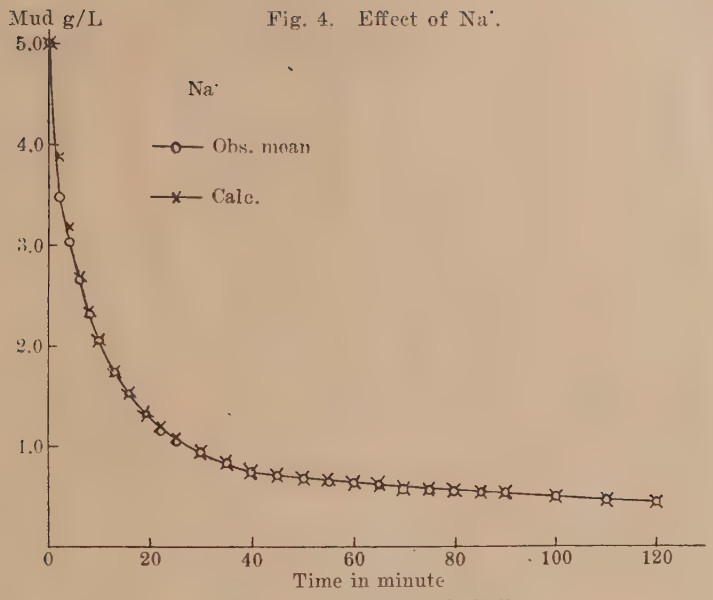


Fig. 4. Effect of $Na^{\cdot}$.

Table 3. Effect of $Ca^{\cdot\cdot}$.

Time	(1)		(2)		Mean of (1) (2)	
	Defl.	Mud	Defl.	Mud	Observed	Calculated
min	cm	g/L	cm	g/L	g/L	g/L
0	—	—	—	—	—	—
2	3.9	3.53	5.5	2.93	3.23	3.33
4	5.3	3.00	6.9	2.58	2.79	2.76
6	6.5	2.67	8.2	2.33	2.50	2.36
8	8.5	2.27	9.8	2.08	2.17	2.05
10	12.0	1.81	13.6	1.73	1.77	1.83
13	16.1	1.58	15.7	1.60	1.59	1.56
16	22.2	1.33	21.2	1.35	1.34	1.36
19	25.8	1.21	25.4	1.22	1.22	1.21
22	31.0	1.06	28.9	1.13	1.09	1.09
25	34.0	0.98	32.9	1.02	1.00	0.97
30	39.8	0.85	39.0	0.87	0.86	0.86
35	44.1	0.76	45.0	0.75	0.76	0.76
40	49.0	0.72	50.0	0.72	0.72	0.72
45	51.3	0.70	54.7	0.68	0.69	0.69
50	55.3	0.68	57.3	0.66	0.67	0.68
55	59.1	0.65	60.2	0.64	0.65	0.64
60	63.9	0.62	63.4	0.63	0.62	0.63
65	67.0	0.60	65.9	0.61	0.60	0.60
70	70.2	0.57	68.0	0.59	0.56	0.58
75	71.9	0.56	70.0	0.57	0.57	0.56
80	76.0	0.53	72.5	0.55	0.54	0.55
85	78.7	0.51	75.2	0.53	0.52	0.53
90	80.2	0.50	76.7	0.52	0.51	0.52
100	84.5	0.48	79.4	0.50	0.49	0.49
110	88.5	0.44	84.4	0.47	0.46	0.46
120	91.0	0.42	86.0	0.45	0.43	0.44

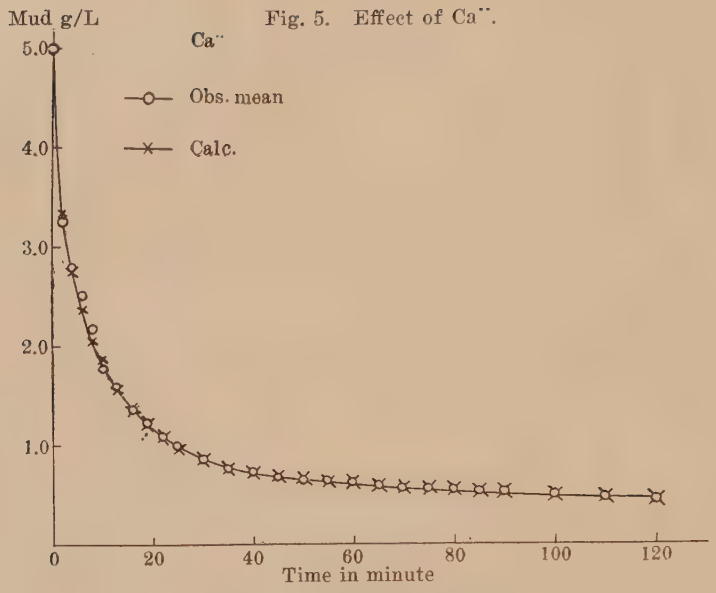


Fig. 5. Effect of Ca^{++}.

Table 4. Effect of Mg^{++}.

Time	(1)		(2)		Mean of (1) (2)	
	Defl.	Mud	Defl.	Mud	Observed	Calculated
min	cm	g/L	cm	g/L	g/L	g/L
0	—	—	—	—	—	—
2	4.9	2.98	4.2	3.22	3.07	2.94
4	6.5	2.57	6.2	2.65	2.61	2.54
6	8.4	2.23	8.0	2.30	2.27	2.17
8	11.6	1.84	9.3	2.10	1.97	1.93
10	14.3	1.63	13.2	1.72	1.68	1.73
13	18.5	1.40	17.7	1.43	1.42	1.49
16	23.7	1.22	22.0	1.27	1.25	1.32
19	28.4	1.08	26.7	1.13	1.11	1.18
22	31.4	1.02	31.4	1.02	1.02	1.07
25	34.1	0.95	35.0	0.93	0.94	0.97
30	39.0	0.84	42.0	0.78	0.81	0.85
35	43.2	0.75	46.0	0.73	0.74	0.77
40	47.2	0.73	49.7	0.71	0.72	0.74
45	50.2	0.71	54.5	0.68	0.70	0.71
50	53.5	0.68	58.0	0.66	0.67	0.69
55	56.7	0.67	61.2	0.63	0.65	0.67
60	59.8	0.64	64.5	0.61	0.63	0.65
65	61.7	0.63	67.5	0.59	0.61	0.63
70	63.7	0.62	70.5	0.57	0.59	0.61
75	65.6	0.60	73.4	0.54	0.57	0.59
80	68.3	0.58	75.7	0.53	0.56	0.57
85	70.2	0.57	77.8	0.52	0.55	0.55
90	72.2	0.55	79.5	0.50	0.53	0.54
100	76.0	0.53	83.2	0.48	0.51	0.52
110	78.2	0.52	85.4	0.46	0.49	0.49
120	81.0	0.49	88.0	0.44	0.47	0.47

Fig. 6. Effect of $Mg^{\cdot\cdot}$.

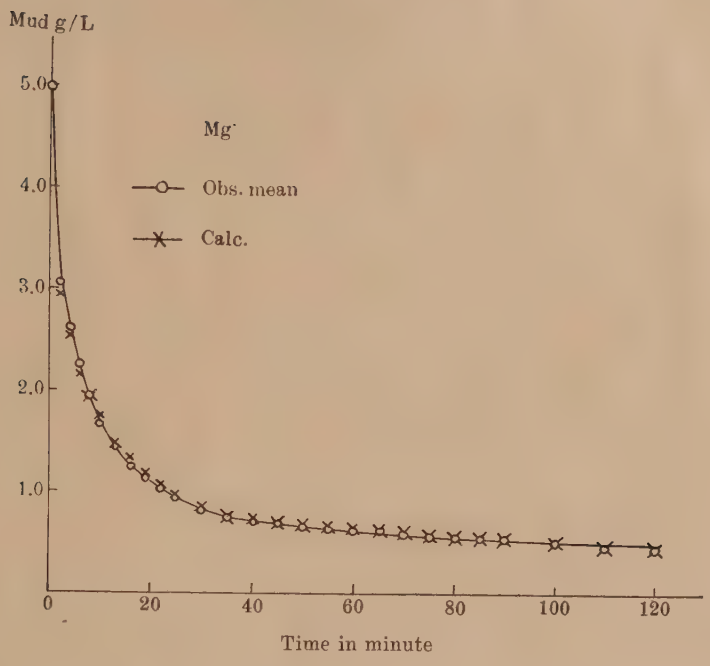


Table 5. Effect of $K^{\cdot}$.

Time	Defl.	Mud	Time	Defl.	Mud
min	cm	g/L	min	cm	g/L
0	—	—	60	8.1	2.30
3	3.2	3.95	80	8.8	2.17
6	4.2	3.43	100	9.7	2.05
9	4.6	3.25	120	10.3	1.98
12	4.7	3.20	150	11.7	1.85
15	5.0	3.10	180	13.3	1.72
20	5.4	2.95	240	15.9	1.54
25	5.7	2.85	300	18.9	1.39
30	5.9	2.80	360	22.5	1.25
40	6.9	2.53	420	28.5	1.07
50	7.7	2.37	480	31.0	1.03

Fig. 7. Effect of K'.

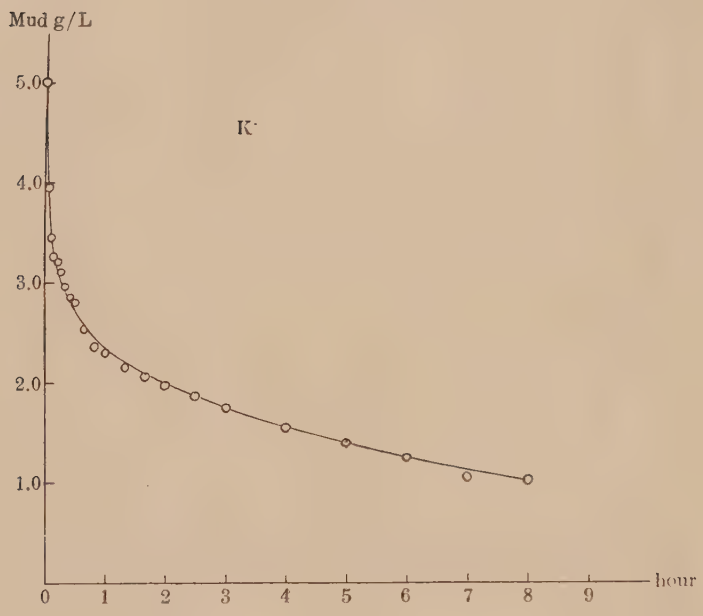


Table 6. Case of no-salt.

Time	(1)		(2)		(3)		Mean of (1) (2) (3)
	Defl.	Mud	Defl.	Mud	Defl.	Mud	Mud
min	cm	g/L	cm	g/L	cm	g/L	g/L
0	—	—	—	—	—	—	—
5	2.5	4.00	3.9	3.47	3.5	3.57	3.68
10	4.2	3.33	4.6	3.18	4.1	3.27	3.26
20	5.0	3.03	5.5	2.88	4.6	3.07	3.00
30	6.0	2.72	5.9	2.77	4.8	3.00	2.83
40	6.0	2.72	6.3	2.67	5.2	2.87	2.75
50	6.5	2.58	6.9	2.52	5.6	2.75	2.62
60	7.0	2.47	7.4	2.40	5.9	2.68	2.52
80	7.5	2.37	8.0	2.30	6.1	2.63	2.43
100	8.0	2.27	8.8	2.13	6.6	2.52	2.31
120	8.3	2.23	9.4	2.07	7.0	2.43	2.25
150	9.0	2.10	10.1	1.97	7.4	2.35	2.14
180	9.5	2.03	11.1	1.87	7.7	2.28	2.06
240	11.0	1.88	12.5	1.75	8.5	2.15	1.92
300	12.0	1.80	14.3	1.62	9.4	2.02	1.83
360	13.0	1.72	15.7	1.52	10.4	1.90	1.72
420	14.5	1.62	17.5	1.43	11.2	1.82	1.62
480	16.0	1.53	19.9	1.32	12.0	1.73	1.54
540	18.0	1.43	21.7	1.25	13.0	1.66	1.45
600	20.1	1.33	24.6	1.15	13.8	1.60	1.36

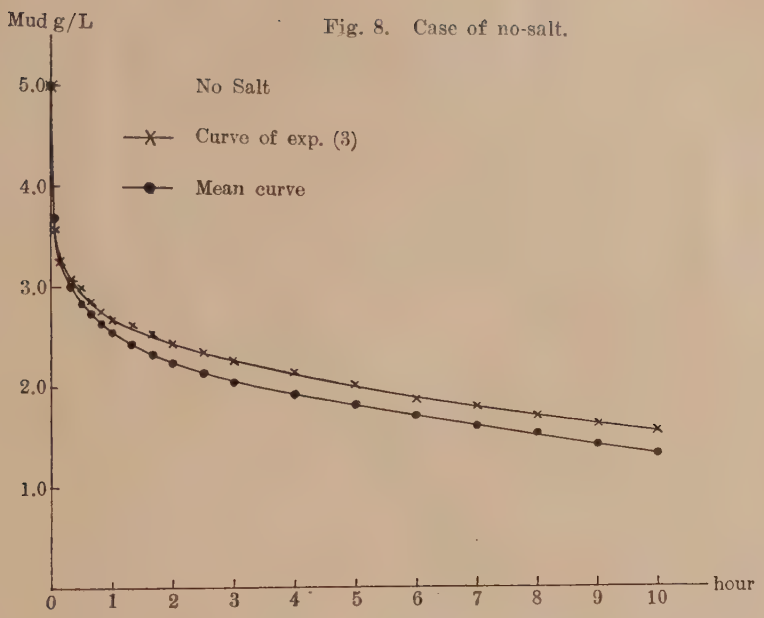


Fig. 8. Case of no-salt.

Among these, the actions of $Na^{\cdot}$, $Ca^{\cdot\cdot}$, and $Mg^{\cdot\cdot}$ upon the sedimentation of mud are very conspicuous, and since such effect is obviously due to the impact and flocking of mud particles de-electrified by the influence of cations, the process is analogous to a chemical action of the second degree, so that we may assume that

$$\frac{dC}{dt} = kC^2, \qquad \text{(i)}$$

or its equivalent

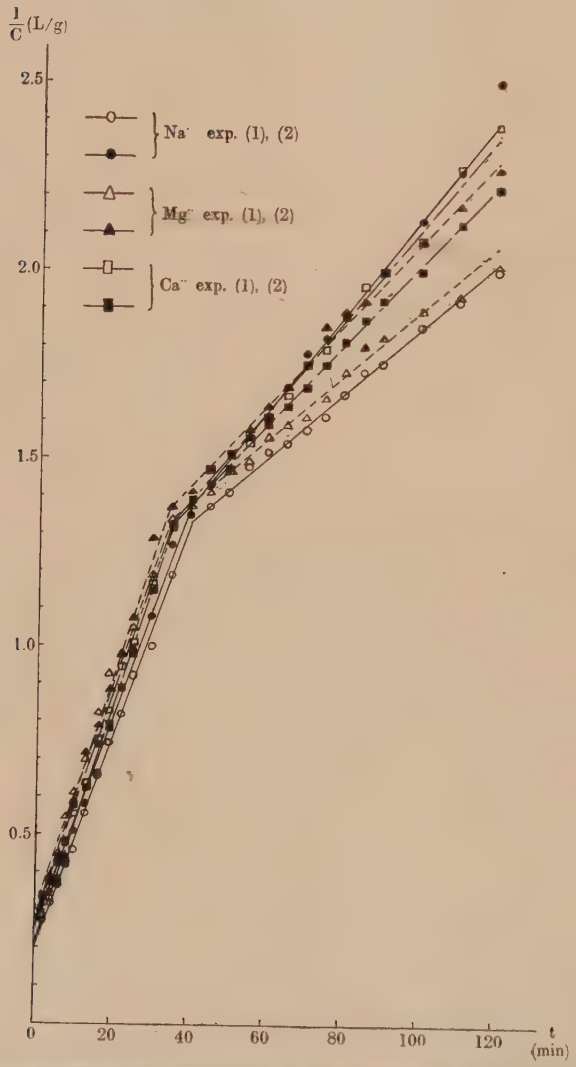
$$\frac{1}{C} = \frac{1}{C_0} + kt, \qquad \text{(ii)}$$

where C is the concentration of mud at the time t, and k is a coefficient depending on the nature of the mud and the cations employed, and C_0 corresponds to the initial concentration.

In order to determine k and C_0 from the observed data, we plot the measured values of 1/C and t as ordinates and abscissa, and we get Fig. 9.

This diagram shows that the relation between 1/C and t is represented by two, not one, straight lines meeting at a certain point $(1/C_1, t_1)$, and hence we must consider that the value of k takes two different values k′ and k″ before and after $(1/C_1, t_1)$. Thus Fig. 9 gives the following empirical formulae:

Fig. 9. Relation between 1/C and t.



Cation	Exp. No.	First stage	Second stage
Na^{++}	(1)	$1/C = 2.000 + 0.280t$	$1/C = 13.200 + 0.087\,(t - t_1)$
	(2)	$1/C = 2.200 + 0.290t$	$1/C = 13.600 + 0.128\,(t - t_1)$
Ca^{++}	(1)	$1/C = 2.200 + 0.313t$	$1/C = 13.200 + 0.122\,(t - t_1)$
	(2)	$1/C = 2.600 + 0.303t$	$1/C = 13.205 + 0.106\,(t - t_1)$
Mg^{++}	(1)	$1/C = 3.000 + 0.295t$	$1/C = 13.350 + 0.085\,(t - t_1)$
	(2)	$1/C = 2.630 + 0.313t$	$1/C = 13.130 + 0.110\,(t - t_1)$

In these formulae the units of C and t are taken gramme per litre and minute respectively, and t_1 is determined as 40 min for the $Na^{\cdot}$ experiment and 35 minutes for the $Ca^{\cdot\cdot}$ and $Mg^{\cdot\cdot}$ experiments.

The mean of the values of C and t calculated by these empirical formulae (1) and (2) are also plotted in Figs. 4, 5, 6, and they are very well coincident with the observed values. But it is here to be noted that the numerical values of the coefficients k and C_0 will of course depend on the initial concentration as well as upon the nature of the mud and cation used.

From the above investigation we may say that, for the excitation of mud sedimentation in sea water, the three cations $Na^{\cdot}$, $Mg^{\cdot\cdot}$ and $Ca^{\cdot\cdot}$ are almost equally effective, although the effect of $Na^{\cdot}$ seems to be a little weaker than that of the other two in the first stage before t_1.

Next we observed the action of $K^{\cdot}$ in the sea water, as shown in Fig. 7. The effect of $K^{\cdot}$ is very small and the sedimentation of mud is not much more accelerated than in the case of no-salt (Fig. 8). For instance, mud water of initial concentration of about 5 g/L becomes 1.5 g/L in 10 hours in the case of no-salt and becomes 1.0 g/L in 8 hours in the case of $K^{\cdot}$, while 0.5 g/L is attained only after 2 hours in the case of $Na^{\cdot}$, $Mg^{\cdot\cdot}$ or $Ca^{\cdot\cdot}$ with the concentration as in normal sea water. Such slow sedimentation as in the case of $K^{\cdot}$, as well as of no-salt, can not be represented by the simple eq. (ii), showing that in these cases the sedimentation is complex owing to the electrification and other nature of the fine particles of mud.

Lastly let us consider the reason why the coefficient k takes two different values when rapid sedimentation of mud particles occurs under the influence of strong cations. The particles of mud used in our experiments probably consisted of two groups, A and B, entirely different in nature (size, etc). If so, in the first stage of sedimentation most of the larger grains of type A will coagulate and precipitate, in addition to the slower precipitation of grains of kind B, and consequently the coefficient k will take a large value k'. After all the grains of type A have settled, however, only the remaining grains of type B will continue to precipitate which will have a smaller value of coagulation coefficient (k''), and this is nothing but the second stage of sedimentation. We think that such an explanation is adequate even though it is not unique. The fact that $k' \fallingdotseq 3k''$ seems to have some meaning for the constitution of mud grains, and we even expect that we might meet cases in which there were three or even more different

values of k, according to the circumstances.

B) Experiments by the second method

Changing the initial concentration of mud and cations, we carried out numerous experiments according to the second method described above. The following Tables 7 to 10 are the results thus obtained, in which we tabulated the time when the upper 10 cm scale on test tubes becomes visible through water. Blanks there are due to the failure to read the tubes during the night.

Table 7. Exp. with $Na^{\cdot}$.

Normality (N)	$\log_{10}\frac{1}{N}$	Time when the upper 10 cm becomes visible through water			
		mud 5 g in 400 cc.	5 g in 800 cc.	5 g in 1200 cc.	5 g in 1600 cc.
		d h m	d h m	d h m	d h m
1	0	19	32	37	25
$\frac{1}{2}$	0.301	19	48	42	26
$\frac{1}{5}$	0.699	25	1 20	47	27
$\frac{1}{10}$	1.000	30	1 20	1 20	58
$\frac{1}{20}$	1.301	36	2 1	1 40	1 40
$\frac{1}{30}$	1.477	1 30	2 2	3 0	2 10
$\frac{1}{40}$	1.602	2 0	3 30	3 30	5 10
$\frac{1}{50}$	1.699	2 0	4 0	4 30	5 10
$\frac{1}{60}$	1.778	—	4 30	4 30	7 40
$\frac{1}{70}$	1.845	4 0	6 20	6 30	—
$\frac{1}{80}$	1.903	5 0	7 40	7 0	—
$\frac{1}{90}$	1.954	6 30	21	—	—
$\frac{1}{100}$	2.000	6 30	1 1	—	23
$\frac{1}{120}$	2.079	21	1 1	22	1 8
$\frac{1}{140}$	2.146	1 1	—	1 7	2 0
$\frac{1}{160}$	2.204	2 4	—	1 20	—
$\frac{1}{180}$	2.255	3	1 22	2 8	—
$\frac{1}{200}$	2.301	3		3	—

Table 8. Exp. with $Ca^{..}$.

Normality (N)	$\log_{10}\frac{1}{N}$	Time when the upper 10 cm becomes visible through water								
		mud 5 g in 400 cc.			5 g in 800 cc.			5 g in 1200 cc.		
		d	h	m	d	h	m	d	h	m
$\frac{1}{5}$	0.699			22			39			35
$\frac{1}{10}$	1.000			22			38			35
$\frac{1}{20}$	1.301			22			40			35
$\frac{1}{30}$	1.477			20			37			35
$\frac{1}{40}$	1.602			25			41			35
$\frac{1}{50}$	1.699			28			41			38
$\frac{1}{60}$	1.778			23			38			38
$\frac{1}{70}$	1.845			28			40			38
$\frac{1}{80}$	1.903			29			38			38
$\frac{1}{90}$	1.954			30			41			38
$\frac{1}{100}$	2.000			30			40			53
$\frac{1}{120}$	2.079			34			43			46
$\frac{1}{140}$	2.146			34			39			49
$\frac{1}{160}$	2.204			31			43			49
$\frac{1}{180}$	2.255			36			40			57
$\frac{1}{200}$	2.301			35		1	30		2	10
$\frac{1}{300}$	2.477			53		2	40		4	0
$\frac{1}{400}$	2.602		3	10		7	0		12	
$\frac{1}{500}$	2.699		6	0		12			23	
$\frac{1}{600}$	2.778		12			16			24	
$\frac{1}{700}$	2.845		16			22		1	20	
$\frac{1}{800}$	2.903		18		1	20		2		
$\frac{1}{900}$	2.954		20		2	13		2		
$\frac{1}{1000}$	3.000	2			2	17		2		

Normality (N)	$\log_{10}\frac{1}{N}$	Time when the upper 10 cm becomes visible through water
		5 g in 1600 cc.
		d h m
$\frac{1}{5}$	0.699	38
$\frac{1}{10}$	1.000	38
$\frac{1}{20}$	1.301	38
$\frac{1}{30}$	1.477	39
$\frac{1}{40}$	1.602	40
$\frac{1}{50}$	1.699	42
$\frac{1}{60}$	1.778	55
$\frac{1}{70}$	1.845	55
$\frac{1}{80}$	1.903	55
$\frac{1}{90}$	1.954	55
$\frac{1}{100}$	2.000	1 4
$\frac{1}{120}$	2.079	1 20
$\frac{1}{140}$	2.146	1 30
$\frac{1}{160}$	2.204	1 30
$\frac{1}{180}$	2.255	1 40
$\frac{1}{200}$	2.301	2 40
$\frac{1}{300}$	2.477	4 30
$\frac{1}{400}$	2.602	16
$\frac{1}{500}$	2.699	23
$\frac{1}{600}$	2.778	1 4
$\frac{1}{700}$	2.845	1 20
$\frac{1}{800}$	2.903	1 20
$\frac{1}{900}$	2.954	2
$\frac{1}{1000}$	3.000	3

Table 9. Exp. with $Mg^{\cdot\cdot}$.

Normality (N)	$\log_{10}\frac{1}{N}$	Time when the upper 10 cm becomes visible through water											
		mud 5 g in 400 cc.			5 g in 800 cc.			5 g in 1200 cc.			5 g in 1600 cc.		
		d	h	m	d	h	m	d	h	m	d	h	m
1	0			22			27			59			52
$\frac{1}{2}$	0.301			22			27			59			52
$\frac{1}{5}$	0.699			21			27			49			42
$\frac{1}{10}$	1.000			16			28			39			53
$\frac{1}{20}$	1.301			23			28			59			53
$\frac{1}{30}$	1.477			23			28		1	0			43
$\frac{1}{40}$	1.602			23			37		1	0			34
$\frac{1}{50}$	1.699			23			29			40		1	0
$\frac{1}{60}$	1.778			24			29			50			54
$\frac{1}{70}$	1.845			17			30		1	0			44
$\frac{1}{80}$	1.903			17		1	0		1	0		1	5
$\frac{1}{90}$	1.954			24		1	0		1	10			45
$\frac{1}{100}$	2.000			24		1	0		1	10		1	5
$\frac{1}{120}$	2.079			39		1	0		1	10			55
$\frac{1}{140}$	2.146			39		1	0		1	0		1	30
$\frac{1}{160}$	2.204			50		1	0		1	30		2	0
$\frac{1}{180}$	2.255			50		1	30		1	50		1	40
$\frac{1}{200}$	2.301			50		1	30		1	0		1	40
$\frac{1}{300}$	2.477		1	50		3	50		4	15		4	30
$\frac{1}{400}$	2.602		2	40		3	50		4	15		5	0
$\frac{1}{500}$	2.699		4	20		6	30		8	0		9	0
$\frac{1}{600}$	2.778		4	50		7	30		22			22	
$\frac{1}{700}$	2.845		6	20		15	30	1	0		1	0	
$\frac{1}{800}$	2.903		15			17	30	1	17		1	17	
$\frac{1}{900}$	2.954		22			22	30	1	21		2		
$\frac{1}{1000}$	3.000	1	1			—			—				

Table 10. Exp. with K'.

Normality (N)	$\log_{10}\frac{1}{N}$	Time when the upper 10 cm becomes visible through water											
		mud 5 g in 400 cc.			5 g in 800 cc.			5 g in 1200 cc.			5 g in 1600 cc.		
		d	h	m	d	h	m	d	h	m	d	h	m
$\frac{1}{5}$	0.699			50		1	5		1	25		1	50
$\frac{1}{10}$	1.000		1	10		1	45		1	30		6	0
$\frac{1}{20}$	1.301		1	50		3	0		5	0		6	30
$\frac{1}{30}$	1.477		2	50		5	55		9	0		22	30
$\frac{1}{40}$	1.602		3	10		15	30	1	7		1	5	
$\frac{1}{50}$	1.699		7	40		17	0	1	7		2	0	
$\frac{1}{60}$	1.778		13	0		—		1	7		2	0	
$\frac{1}{70}$	1.845		14	0		—		1	22		2	5	
$\frac{1}{80}$	1.903		17	0	1	7		1	22		1	20	
$\frac{1}{90}$	1.954	1	0		2	0		1	22		1	20	
$\frac{1}{100}$	2.000	1	0		2	0		2	2		1	20	
$\frac{1}{120}$	2.079	1	7		2	20		2	12		2	0	
$\frac{1}{140}$	2.146	1	19		2	20		2	12		2	0	
$\frac{1}{150}$	2.204	2	22		4	19		2	17		2	0	
$\frac{1}{180}$	2.255	3	3		4	19		2	17		2	0	
$\frac{1}{200}$	2.301	3	7		3	20		2	17		2	20	
$\frac{1}{300}$	2.477	3	7		4	6		2	21		2	20	
$\frac{1}{400}$	2.602	3	22		4	19		3	0		2	20	
$\frac{1}{500}$	2.699	4	10		4	19		3	0		2	20	

For representing these results in graphs, it is convenient to use the logarithms of inverse of normality of cations as abscissa. Fig. 10 to 13 are thus drawn; but in the earlier stage only a few observed data are plotted, the greater number of data being omitted, in order to avoid confusion, and in the later stage also the data requiring days for precipitation are omitted for the purpose of saving diagram space.

From the above tables or figures we see that:

1) With sufficient concentrations of cations, sedimentation of

Fig. 10. Exp. with $Na^{\cdot}$.

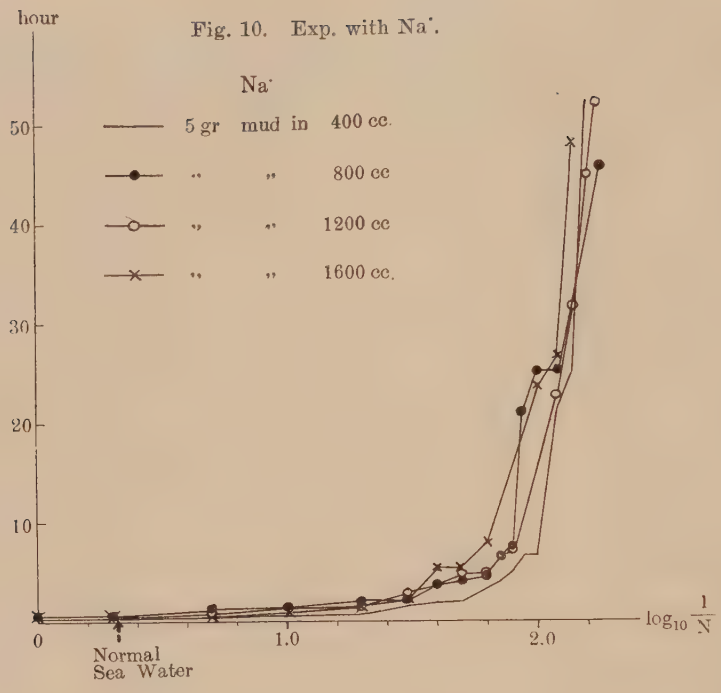


Fig. 11. Exp. with $Ca^{\cdot\cdot}$.

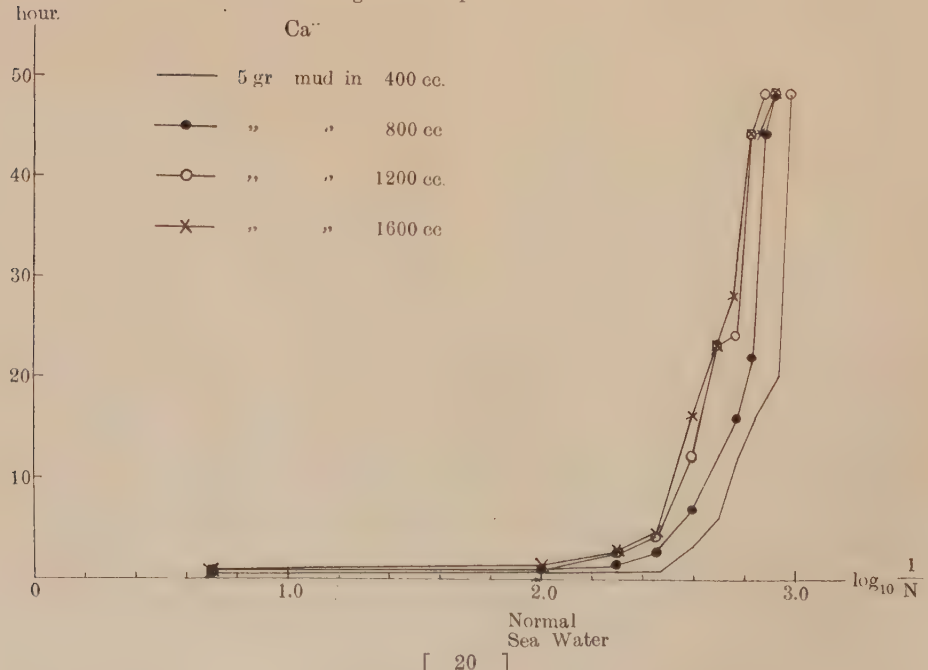


Fig. 12. Exp. with $Mg^{\cdot\cdot}$.

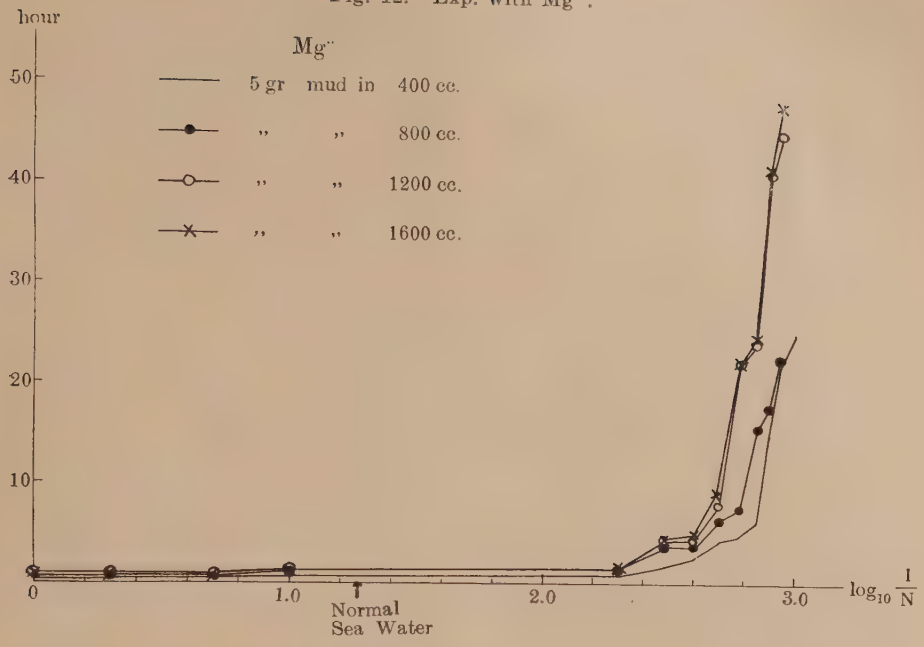
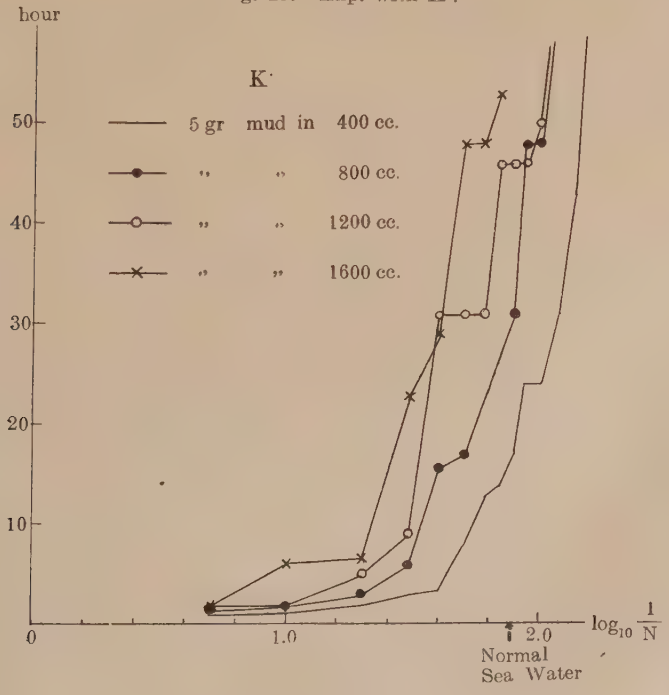


Fig. 13. Exp. with $K^{\cdot}$.



mud always occurs in a very short time (within a few tens of minutes in our exp.) irrespective of the type of cations employed.

2) As the ion-concentration decreases, the difference of ions becomes distinct, and in all cases there exists a critical concentration at which the action of the ions decreases abruptly and mud sedimentation begins to require a very long time (hours and even days).

3) As exciters for the sedimentation of mud-suspensoid, $Mg^{\cdot\cdot}$ and $Ca^{\cdot\cdot}$ are of nearly equal strength, and $Na^{\cdot}$ comes next and $K^{\cdot}$ is much weaker than the other three.

4) As to the initial concentration of mud, a striking result is obtained, i.e., the greater the mud quantity, the shorter is the time required for its total sedimentation. This is perhaps due to easiness of impact and flocking of mud particles into larger grains.

In addition to the above experiments, a special test for the relative effect of each cation of concentration the same as in normal sea water (Dittmar's table[1]) was made by the second method also, the result by the first method being explained already before.[2] Table 11 shows the result, which gives the time required for each two cm of the scale to become visible through water. The row "mean" denotes the time required for 6 cm to become visible if the process advanced at the same velocity as the mean for the whole length of the tube to become visible.

Table 11. Relative effect of each cation in normal sea water.

(Initial turbidity: 5 gr mud in 400 cc of water)

Visible down to	$Mg^{\cdot\cdot}$	$Ca^{\cdot\cdot}$	$Na^{\cdot}$	$K^{\cdot}$	Sea-water
2 cm	11 min	10 min	16 min	46 min	15 min
4	14	14	20	58	18
6	15	17	21	70	19
8	17	18	22	85	20
10	20	22	26	93	22
mean (6 cm)	15.4	16.2	21.0	70.4	18.8
0 cm	8.3	8.9	15.0	33.5	14.0

1) p. 2.
2) p. 15.

Fig. 14. Relative effect of each cation in the normal sea water. (Initial turbidity: 5 gr mud in 400 cc of Water)

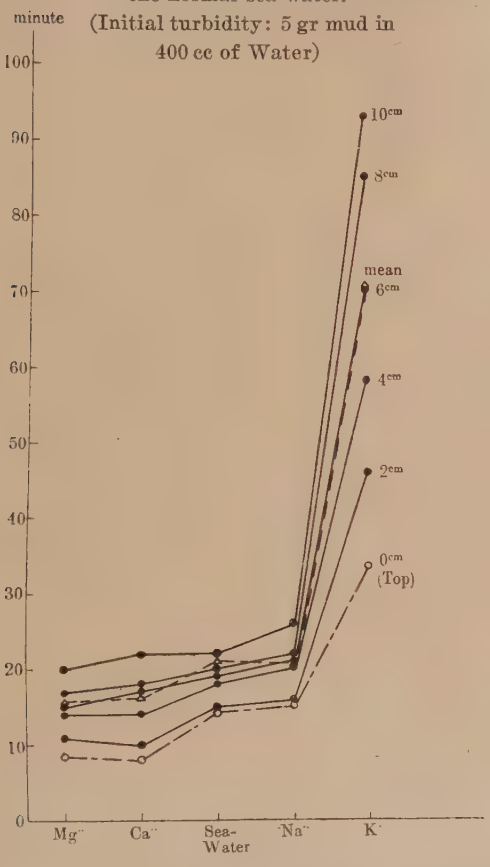


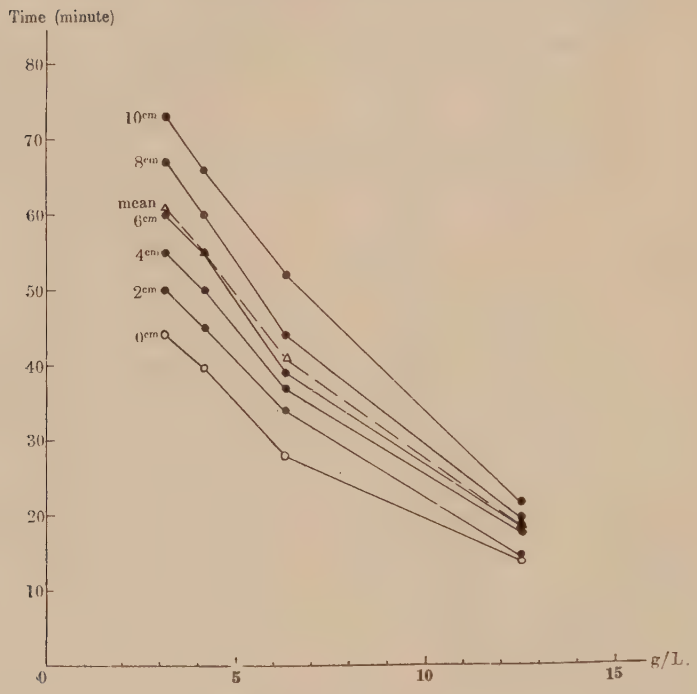
Fig. 14 is the graph drawn with Table 11, and its general nature coincides with the result obtained by the first method. Namely, $Mg^{\cdot\cdot}$ and $Ca^{\cdot\cdot}$ are most effective for mud sedimentation, $Na^{\cdot}$ is a little weaker and $K^{\cdot}$ much weaker, normal sea water itself (containing all four cations $Mg^{\cdot\cdot}$, $Ca^{\cdot\cdot}$, $Na^{\cdot}$ and $K^{\cdot}$) having an effect nearly equal to that of $Na^{\cdot}$.

Further, with various quantity of mud, similar experiments in the normal sea water were repeated, and Table 12 and Fig. 15 are obtained as the result. This verifies very clearly the fact that the greater the initial turbidity the more rapidly the total sedimentation will proceed in the real sea also.

Table 12. Relation of initial turbidity and the time of total sedimentation.

Visible down to	Mud Concentration			
	5 g in 1600 cc (3.13 g/L)	1200 cc (4.17)	800 cc (6.25)	400 cc (12.5 g/L)
2 cm	50 min	45 min	34 min	15 min
4	55	50	37	18
6	60	55	39	19
8	67	60	44	20
10	73	66	52	22
mean (6 cm)	61	55.1	41.1	18.8
0 cm	44	39.8	28.0	14.0

Fig. 15. Relation of initial turbidity and the time of total sedimentation of mud.



Mud quantity in g/L.

III. Summary

In order to ascertain how the sedimentation of mud transported by a river is accelerated when it meets sea water, we experimentally examined the precipitation of mud in water of various degrees of salinity and of turbidity, hoping to supply some data necessary for a consideration of such problems as the mode of deposition on the continental shelves in oceanography or the formation of sedimentary rocks in geology. The chief results of our experiments are as follow:

1) With sufficient concentration of cations, fine mud coagulates always in a very short time (a few tens of minutes) and then will sink down with a uniform velocity.

As the ion-concentration decreases, the coagulation becomes slower, and at a certain critical concentration (ca. 1/100 normality) the effect of ions decreases abruptly so that coagulation of mud particles requires a very long time (many hours or even days).

2) As the exciter of coagulation of fine mud, $Mg^{\cdot\cdot}$ and $Ca^{\cdot\cdot}$ are of nearly equal strength, and $Na^{\cdot}$ comes next and $K^{\cdot}$ is much weaker than the other three.

3) As for the initial quantity of mud, the greater the turbidity, the shorter is the time required for the total coagulation of mud. Very little quantity of mud in a dilute sea-water takes a considerable time for sedimentation.

In conclusion the writers' sincere thanks are due to the Nippon Gakujutu-Shinkô-kwai for the grant given to one of the writers (T. N.) with which this research could be accomplished.

An Interesting Problem Concerning the Marine Fauna in the Japan Sea

By

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It is well known that many species of mollusca which are now considered to be extinct in the seas surrounding Japan have been dredged from the sea-bottom of the Japan sea. Also species of foraminifera, diatoms, sponge spicules and brachiopoda are known to be associated with the above mentioned mollusca. Are these really fossils or are they merely living forms which have been water-worn? This is the problem to be dealt with in this article.

According to the studies by Kuroda and Kikuchi,[1] the molluscan fauna of Toyama Bay, which occupies the area of 137°–137°35′E. Long., and 36°45′–37°30′N. Lat., shows many important features, geologically and geographically. Since their work is so interesting, we freely quote from it.

"Toyama Bay is geologically explained to have been formed by a fault. The 200 meters line of depth lies close to the shore, and this feature is particularly shown at the southern coast; the deepest centre is measured at over 1,400 meters. The shallow littoral bottom is generally sandy, but the deeper the muddier, and at depths over 400 meters the bottom is covered with fine mud. The western border consists mainly of precipiced or rocky beaches of Tertiary sandstone, while the southern coast, especially those off the mouths of the rivers Zôgwanzi,[2] Hayatuki and Kurobe are pebbly to a considerable depth, due to the material carried down by these rivers.

During the years 1929–32, the junior author engaged in the faunal survey of the bay, in which the molluscan investigation by various

1) T. Kuroda and K. Kikuchi: Studies on the Molluscan Fauna of Toyama Bay(1), The Venus, Vol. 4, No. 1, pp. 1–14, 1 pl., 1 map, and 4 text-figs., 1933 (in Japanese with English resume).

2) Geographic names are changed into Japanese system (Nippon-siki).

methods of collection was undertaken. The dredge operations were carried out as many as 63 times from bottom 80–600 meters deep, as well as collecting on the beach from time to time with a constant watch on refuse from the fishermen's nets, or examining the stomach contents of benthonic fishes, etc., and the number of molluscan species amounted to over 500 in all. As there are contained in the lot many species worthy to be remarked, we wish to describe them hereafter in serial succession.

The molluscan fauna of Toyama Bay is very remarkable from the zoogeographical point of view. The characteristic of the fauna, is, first of all, due to the branch of the warm current (Kuro-siwo) which flows along the coast, but the current does not seem to influence the bottom deeper than 300 meters. Thus the molluscan fauna of the bay exhibits three conspicuous facies according to the depth of the habitat, they are:

(1 a) In the tidal zone of the western shore, especially in the vicinity of Nanao Bay, there live, in the soft calcareous sandy rocks, several species of tropic or subtropic boring bivalves, such as *Botula cinnamomea, Coralliophaga coralliophaga,* and *Aspidopholas yoshimurai,* etc. These forms have been entirely unknown or unrecorded from the adjacent waters thus far.

(1 b) From the low tide mark down to several meters' depth, there occur most of littoral species which are very common in the southern and western coast of Honsyû, Sikoku and Kyûsyû.

(2) On the bottom next the former in depth, down to 100 meters, are sublittoral species similar to those of the similar depth in the southern coast of Honsyû, like Sagami and Kii. The representatives of this zone, for example, are, *Turcica imperialis, Turcicula crumpii, Glycymeris rotunda, Chlamys vesiculosa, Siphonalia spadicea,* etc.

(3) On the bottom deeper than 300 meters, the species above mentioned are no more found, but the genuine boreal fauna, such as several species of *Buccinum, Neptunea* (=*Chrysodomus*), *Plicifusus,* etc. In connection with this peculiarity the reader will recollect Mr. Teramachi's interesting paper on the whelk-fishing in Toyama Bay in the previous number of this journal.

These characteristic features in general are evident not only in the molluscan fauna, but also in 400 species of fishes and 120 species of decapod crustaceans we have collected in the bay."

Besides the above quoted valuable paragraphs, Kuroda and

Kikuchi state that there is a saying that Neogene Tertiary shell-beds which are widely distributed in northern Japan are exposed in the sea-bottom of this district. The presence of dead, isolated and discolored shells of *Pecten yessoensis*, *Astarte alaskensis*, *Mercenaria stimpsoni*, and *Nuttallia olivacea*, which are found in the collection, are belived by them to not belong to the recent fauna of the bay.

According to Yokoya,[1] who studied the decapod crustaceans dredged by the surveying ship Sôyô-maru of the Imperial Fisheries Institute, from the continental shelf sea of Japan "Toyama Bay and its neighborhood are rich in fauna of the northwards distributing Decapods." His examples are given below with the depth in meters in brackets, they are:

Pandalus platyceros(311), *P. hypsinotus*(86–247), *Spirontocaris groenlandica* (247–260), *Nectocragon lar* (143–187), *Eupagurus ochotensis* (11–444), *Spirontocaris buinguis* (450–620), *Pandalus borealis* (444), *Crangon communis* (311–390), *Spirontocaris minuta* (669), *Eupagurus anomarus*(91–270), *Nectocrangon toyamaensis*(311), *N. sadoensis*(168), *Sclerocrangon gasuyebi*(110–205).

Since these enumerated species are northwards distributing species having their southern limit in distribution at Toyama Bay, and their smaller depth in regions north of the said Bay, the result reached by Kuroda and Kikuchi coincides with that of Yokoya.

In the case of decapod crustaceans it appears that Noto Peninsula and its vicinity is a boundary for the northern limit of southward distributing species and the southern limit of northwards distributing species, around the depth of 300 meters.

In the case of brachiopoda possessing the soft parts, a conclusion reached by Yokoya for the decapod crustacean and by Kuroda and Kikuchi for the mollusca is met with. For example *Pictothyris picta* (Dillwyn) is found in the southern area of Noto Peninsula but not in its northern. The same occurrence of this species is also found at Tyôsi Peninsula[2] on the Pacific side of Central Japan. Likewise the decapod crustaceans and molluscan faunas also show a similar relation-

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1) Y. Yokoya: On the Distribution of Decapod Crustaceans Inhabiting the Continental Shelf around Japan, etc., Jour. Coll. Agri. Tokyo Imp. Univ., Vol. 12, No. 1, 1933.

2) K. Hatai, A List of the Recent Brachiopoda Dredged from the Littoral Sea of the Pacific Side of Bôsô Peninsula, Central Japan, Rec. Ocean. Wk. Jap., Vol. 8, No. 1, pp. 1–17, 1936.

ship, as would naturally be expected.

The cirripedia,[1] however, do not appear to show such a close relationship as those of the decapod crustaceans, mollusca and brachiopoda; probably they are less sensitive to temperatural change of water.

The oceanographical conditions of the Japanese seas are fairly well known,[2] and at this place it does not seem necessary to repeat the studies by various workers along this line in Japan. The water temperature and salinity down to a depth of 500 meters are known from the studies by Uda. At this place it is necessary to state that at a depth of around 150 meters, the water temperature near Noto Peninsula is the same as that of a similar depth off Tyôsi Peninsula on the Pacific side of central Japan; while the water temperature at a depth of 200 meters in the vicinity of Hukui, south of Noto Peninsula comes in the vicinity of Tyôsi Peninsula at a similar depth. This relationship in water temperature for similar depths at Noto Peninsula and Tyôsi Peninsula is a very significant feature and is closely related with the distribution of the organisms above mentioned.

Thus, we find that the physical conditions at a depth of 150 meters or thereabout in the vicinity of Noto corresponds to that in the vicinity of Tyôsi. Consequently, the studies by Kuroda and Kikuchi of the Mollusca, those by Yokoya on the Decapod Crustaceans, and those by the junior author on the Brachiopoda all agree with the oceanographical surveys made by Uda. Also the zoological provinces established by us[3] are also in accord with the studies by Uda and include the studies by the above mentioned workers.

Studies on the brachiopoda dredged by the surveying ship Sôyô-maru of the Imperial Fisheries Institute, reveal the presence of many specimens which have the aspect of being fossils. For example *Craniscus japonicus* (Adams) and *Terebratalia coreanica* (Adams and Reeve) from the Tyôsen Strait are water-worn, grayish blue in color.

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1) F. Hiro, Report on the Cirripedia Collected by the Surveying Ships of the Imperial Fisheries Experimental Station on the Continental Shelf Bordering Japan, Rec. Ocean. Wk. Jap., Vol. 5, pp. 11–84, 1933.

2) M. Uda, Hydrographical Studies based on Simultaneous Oceanographical Observations made in the Japan Sea and Its Adjacent Waters, etc., Rec. Ocean. Wk. Jap., Vol. 6, No. 1, pp. 19–106, 1934.

3) S. Nomura and K. Hatai, Zoological Provinces in the Japanese Seas, Bull. Biogeogr. Soc. Japan, Vol. 6, No. 21, pp. 207–214, 1 map, 1936.

consist of isolated valves of which, those belonging to *Terebratalia coreanica* are represented by fragments only, these, we believe, are true fossils. In the region between the Tyôsen Strait and Sado Island in the Japan Sea are found many specimens of *Laqueus rubellus* (Sowerby), a large number possess the soft parts and are unmistakably living ones, however, there is a fairly large number of specimens with faded valves which are water-worn and generally isolated, but when the valves are intact, usually the anterior half is lacking. Such a condition is frequently met with in dealing with fossil brachiopoda from the Neogene of Japan.

A specimen of *Coptothyris grayi* (Davidson) dredged by the Husamaru of the Tiba Fisheries Station from off Bosyû, Central Japan, as well as those just mentioned above from the Japan Sea region are, according to the observations of the junior author, more likely to be fossils and, therefore, should not be included in the recent ones when dealing with the problem of distribution. To include such forms in dealing with zoological provinces or distribution is not only dangerous but merely false.

The senior author who studied the molluscan shells found in the bottom mud samples dredged by the Sôyô-maru by the request of H. Niino also noticed such valid phenomena. Consequently, not only from the water-worn shells with faded or no coloration at all, but also from the strong contrast shown by the dead shells to those with the soft parts in geographical distribution, a similar conclusion was reached. However, the molluscs living below the 300 meter line are, as already stated by Kuroda and Kikuchi of the boreal type. This is natural, in the view that the water temperature is lowered with the increase of depth and the influence of oceanic currents is not or at least hardly felt.

The bottom material of the seas around Japan are fairly well known through the extensive dredge operations and other oceanographical observations made by the surveying ships Sôyô-maru, Misago-maru, Hukui-mura, Sitito-maru, Husa-maru and others. Although many surveys have already been made so far, there is not little literature in concern, and of importance to the present article are the interesting and valuable papers by H. Niino of the Imperial Fisheries Institute. From his works may be found many interesting data concerning the present problem.

In an article entitled "Fossil Localities in the Bottom of the Tyôsen

Strait'' Niino[1] records such fossils as, *Lucina civica*(Yok.), *Pecten intuscostatus* Yok., *Pecten heteroglyptus* Yok., *Poromya flexuosa* Yok., *Thyasira bisecta*(Conr.), *Lora yamanii*(Yok.), *Turricula subdeclevis* (Yok.), *Turbonilla morsei* Yok., *Epitonium ojiense*(Yok.), and *Carcharius cuspidatus*(Ag.), and also *Terebratalia coreanica*(Adams and Rve.), *Glycymeris yessoensis*(Sow.), *Arca boucardi* Jouss., *Venericardia ferruginea*(A. Ad.), *Anomia lischkei* Daut. and Fisch., *Aloidis venusta*(Gld.), *Siphonalia stearnsii* Pils., *Olivella fulgurata* Ad. and Rve., *Natica janthostoma* Desh., and *Neptunea arthritica* Bern. In another article, Niino[2] also records from the Tyôsen Strait the occurrence of blocks of shale and sandy shale containing fossil organisms.

From the soundings at Musasi-tai in the Japan Sea, Niino[3] records fossil diatoms and fossil sponge spicules, as well as rocks closely resembling those of the Tertiary deposits developed in the adjoining terrestrial region.

From his[4] studies on the soundings from the banks between Oga Peninsula and Sado Island in the Japan Sea, fossil diatoms and fossil foraminifera contained in calcareous shale, *Carcharodon* sp., and mollusca now extinct or not known to be living in our seas, such as *Pecten heteroglyptus* Yok., are reported. In that article he states that ''Judging from the lithological characters of the rock fragments dredged, the bed rocks of the banks belong to the Neogene Tertiary which is developed in the oil fields of North-east Japan.''

Consequently, it is evident that from the bottom of the Japan Sea are known fossil foraminifera, sponge spicules, diatoms, mollusca and brachiopoda; rock fragments are closely similar to those making up the Neogene strata of the adjoining terrestrial region; and, the Oyasio-types of mollusca found in the region of the Tugaru Strait[1] extend

1) H. Niino, Fossil Localities in the Bottom of the Tyôsen Strait, Jour. Geogr., Vol. 46, No. 546, pp. 383–386, 1 pl., 1 map, 2 tables, 1934 (in Japanese).

2) H. Niino, On the Occurrence of *Thyasria bisecta* Conrad in the sea-bottom of the Tyôsen Strait, Jour. Geol. Soc. Jap., Vol. 41, No. 487, pp. 176–182, 1 pl., 5 tables, 1934 (in Japanese).

3) H. Niino, On Soundings at Musasi-tai, Geogr. Rev. Jap., Vol. 12, No. 2, pp. 85–95, 1 pl., 3 tables, 1936) (in Japanese).

4) H. Niino, On the Soundings from the Banks between the Oga Peninsula and Sado Island, in the Northeastern Part of the Japan Sea, Jour. Imp. Fisher., Inst., Vol. 31, No. 1, pp. 11–33, 4 pls., 9 tables, 2 maps, 1935.

5) H. Niino, Bottom Material of the Western Part of the Tugaru Strait, Jour. Geol. Soc. Jap., Vol. 41, No. 495, pp. 713–726, 5 tables, 1934 (in Japanese).

their distribution as far south as the Tyôsen Strait, i.e., below the 150 meters bathymetric lines. From the western part of the Tugaru Strait, NIINO records the occurrence of blocks of shale and sandy shale containing fossils.

From the many valuable papers by NIINO, it is also evident that the banks which are separated from the mainland by an intervening deep, are made up of Neogene rocks which contain fossils, and that, there has been a recent submergence of the land.

From the soundings on the banks of Senoumi in Suruga Bay on the Pacific NIINO[1] records the finding of fossiliferous sandstone, gravels with bore-holes of mollusca, and finds evidence for the recent submergence of land. Fossil foraminifera and rock fragments similar to those making up the Neogene strata of the adjoining terrestrial region are also recorded from the Pacific by NIINO.[2]

It may be possible that the banks in the Japan Sea, although isolated from one another yet roughly parallel to the coast line of the mainland, are due to faulting or submarine tectonic lines as reported by YABE and TAYAMA.[4] According to YABE and TAYAMA, "There are tectonic lines almost parallel to the general trend of coast line and others disposed more or less radial or oblique to it. We find good examples of the former along the Japan Sea coast between off Tugaru Peninsula and off Tango Peninsula, where several parallel tectonic lines rise to four narrow, horst-like, elevated strips in parallel position; the Yamato Bank is probably a horst lying farther outside the disturbed zone." There is also a possibility of the tectonic lines(submarine) of YABE and TAYAMA having very close relationship with the Oti Graben[1] of Noto and in reality may be an extension of it, the horst-like elevations being the remnants of the sides of the graben; if this is possible, then probably the Oti graben may have formerly extended as far north as indicated by the banks(submarine) and as far south as Wakasa Bay,

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1) H. NIINO, On the Soundings from the Banks of Senoumi in the Bay of Suruga, Japan, Jour. Imp. Fisher. Inst., Vol. 29, No. 2, pp. 69–91, 3 pls., 9 tables, 1 map, 1934.

2) H. NIINO, On Soundings at Tosabae, Geogr. Rev. Jap., Vol. 11, No. 8, pp. 679–687, 2 pls., 2 figs., 1935 (in Japanese).

3) H. YABE and R. TAYAMA, Bottom Relief of the Sea Bordering the Japanese Islands and Korean Peninsula, Bull. Earthq. Res. Inst. Imp. Univ. Tokyo, Vol. 12, No. 3, pp. 539–565, 17 figs., 3 maps, 1934 (in Japanese with English summary).

4) Y. OTUKA, The Oti Graben in Southern Noto Peninsula, Japan, Bull. Earthq. Res. Inst. Imp. Univ. Tokyo, Vol. 13, Pts. 1 and 3, 1935.

where are also found banks.

The submarine tectonic lines dealt with by YABE and TAYAMA are of much interest in the view that the banks dealt with by NIINO comprise Neogene rocks similar to those making up the Neogene strata of the adjoining terrestrial region on the one hand, and the occurrence of fossil mollusca, sponge spicules, diatoms and foraminifera in the sea bottom on the other. Even if the submarine tectonic lines are not related to the Oti Graben of southern Noto Peninsula, it seems that there is a possibility of the Daisyaka shell-beds[1] so well developed in Mutu province, Sado Island and Oga Peninsula etc. of having been submerged through the agency of the tectonic lines, and now to be represented by the banks dealt with by NIINO. Consequently, if such an assumption be reliable, then it follows that the fossils, or quite fossil-like forms so frequently dredged by NIINO,[2] mentioned by KURODA and KIKUCHI in their article on the recent molluscan fauna of Toyama Bay, and the brachiopods studied by the junior author of belonging to the Daisyaka shell-beds which are possibly now submerged below the sea surface. Also, from the limited distribution of the Daisyaka shell-beds, their characteristic fauna, and their relation to the fauna found below or in the vicinity of the 150–200 meter bathymetric line in the Japan sea and both to the distribution of such characteristic forms, it seems quite reasonable to assume that the many fossils dredged by NIINO and the mollusca dealt with by the senior author and the brachiopods mentioned by the junior author to be merely components of the Daisyaka shell-beds (=Sawane Beds of Sado and Sibikawa Beds of Oga Peninsula). Since the Daisyaka shell-beds are made up of loose sandstone which is either muddy or pebbly in places and carry many well preserved *mollusca, foraminifera, brachiopoda, bryozoa, sponge spicules* and etc., it is possible that upon submergence of such a strata, the sandgrains will part and the fossils become freed from the matrix. Another view to uphold the statement that below or in the vicinity of

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1) S. NOMURA and K. HATAI, Pliocene Mollusca from the Daisyaka Shell-Beds in the Vicinity of Daisyaka, Aomori-ken, Northeast Honsyû, Japan, Saitô Hô-on Kai Mus., Res. Bull. No. 6, pp. 83–142, 5 pls., 1935.

2) H. NIINO: Exposure of Sedimentary Rocks in the Sea Bottom off Sikoku and Ôsumi Strait along the Pacific coast of Japan, Jour. Geogr. Rev. Jap., Vol. 12, No. 9, pp. 814–827, 1936 (in Japanese with English resume).

„ :Discovery of *Pecten* (*Patinopecten*) *tokyoensis* TOKUNAGA, from various localities in the Sea Bottom of South-western Japan, Jour. Geogr., Vol. 48, No. 570, pp. 359–362, 2 pls., 1936 (in Japanese).

the 150–200 bathymetric line fossils are frequently dredged, is the valid geographic distribution of such genera as *Astarte* in the Japan Sea, and the strongly contrasting distribution shown by marine organisms in which the soft parts are retained to those in which the shells are water-worn, discolored, isolated, encrusted with bryozoa and with the aspect of being real fossils.

It is only natural to bring about conclusions with known data and to neglect such data is not manly; however, although we are now in such an opinion as above mentioned, we certainly recognize the fact that future dredgings and other oceanographical observations are necessary to make valid our opinion, even though we know of the presence of so many fossils, sandstones and shales bearing fossils and many other phenomena as mentioned above.

In closing we wish to record our thanks to Prof. H. Yabe of the Institute of Geology and Palaeontology, Tôhoku Imperial University, Sendai, for kindly rereading and making possible the publication of this short note. Acknowledgements are also due to Mr. R. Tayama of the same Institute for suggestions and to Mr. H. Nuno of the Imperial Fisheries Institute, Tokyo, for several data used in this article.

Annotated List of the Ophiurians dredged from the Pacific Coast of Tiba Prefecture*

By

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The species of ophiurians enumerated in the following list was obtained by the surveying ship Husa-maru of the Tiba Fisheries Experimental Station from the Pacific coast of Tiba prefecture during the years 1931–1933. Under the direction of Mr. K. Suganuma, Director of the Station, dredge operation and other oceanographical observations were also performed. There are about one hundred and thirty specimens in the collection, these represent over fourteen species in eleven genera. Although none of them are new to science, they are of interest from the view of distribution as some of their localities are new.

The ophiurians dealt with in this note are stored in the Institute of Geology and Palaeontology, Tôhoku Imperial Univeristy, Sendai. The species here enumerated are 14 in number; of them, 5 belong to *Phrynophiurida*, 6 to *Gnathophiurida* and 3 to *Chilophiurida*. Those which were either indeterminable or doubtfully identified are not mentioned in the present list.

Here I wish to express my sincere thanks to Prof. H. Yabe of the Institute of Geology and Palaeontology, Tôhoku Imperial University, Sendai, for rereading and making possible the publication of this short note. Thanks are also due to the Director Mr. K. Suganuma and

*) This article is a continuation of the reports on the material collected by the "Husa-Maru" of the Tiba Fisheries Experimental Station at Tateyama. The First article was by K. Okamura entitled, "Notes on Algae dredged from the Pacific Coast of Tiba Prefecture"; see Rec. Ocean. Wk. Jap., Vol. 6, No. 1, 1934. The second article was by K. Hatai entitled, "A List of the Recent Brachiopoda Dredged from the Littoral Sea of the Pacific Side of Bôsô Peninsula, Central Japan"; see Rec. Ocean. Wk. Jap., Vol. 8, No. 1, 1936. The present article is the third on the materials collected by the Tiba Fisheries Experimental Station.

Messrs. K. Nagami and Takehara of the Tiba Fisheries Experimental Station for their kind offer of the materials to my study and also for their warm hospitality given me during my visit to that Station.

Genus *Ophiomyxa* J. Müller et F. Troschel, 1842

Ophiomyxa J. Müller and F. Troschel, 1842, Syst. Asterid., pp. 84, 108.

Genohaplotype: *Ophiura pentagona* J. Lamarck, 1816, Hist. Nat. Anim. sans Vert., 2, p. 546. (=*Stella regularis* Linck, 1733, Stell. Mar., p. 51, pl. 27, f. 46. Pre-Linnean.).

Type by monotypy.

Ophiomyxa australis C. F. Lütken, 1869

Ophiomyxa australis C. F. Lütken, 1869, Addit. ad Hist. Oph., 3, pp. 45, 99. (Bass Strait; Copenhagen Mus.).—H. L. Clark, 1915, Mem. Mus. Comp. Zool., Harvard College, vol. 25, p. 168, pl. 1, f. 1, 2. (Port Jackson, New South Wales; Mus. Comp. Zool.).—H. Matsumoto, 1917, Journ. Coll. Sci., Imp. Univ. Tokyo, vol. 38, art. 2, p. 19, f. 3. (Sagami Bay, in 456 metres; Matsumoto Coll.; Inst. Geol. & Pal., Tôhoku Imp. Univ.)

Materials: Three specimens. Diameter of disc 3 to 6 mm.

Occurrence: Station 2: off Mera. (Depth not given) (Reg. No. 60301).[1)]

Distribution: Amboina (Th. Lyman): Fiji Islands (Th. Lyman): Ponape (H. L. Clark): Tongatabu Islands (Th. Lyman): Port Jackson (H. L. Clark): Bass Strait (C. Lütken): Victoria (H. L. Clark): New Zealand (R. Koehler): Mauritius (H. L. Clark): Japan; Ryûkyû Islands (Ohshima), Eastern Sea (H. L. Clark), Korean Strait (H. L. Clark), Sagami Bay (H. Matsumoto), off Sunosaki (H. L. Clark).

Genus *Astroceras* Th. Lyman, 1879

Astroceras Th. Lyman, 1879, Bull. Mus. Comp. Zool., Harvard College, vol. 6, p. 62.

Genohaplotype: *Astroceras pergamena* Lyman, 1879, op. cit., p. 62. (Challenger Station 235, in 1003 metres; Brit. Mus.)

Type by monotypy.

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1) Register number of specimen in the collection of the Institute of Geology and Palaeontology, Tôhoku Imperial University, Sendai, Japan.

Astroceras pergamena Th. Lyman, 1879

Astroceras pergamena Th. Lyman, 1879, Bull. Mus. Comp. Zool., Harvard College, vol. 6, p. 62, pl. 18, f. 478–480. (Challenger Station 235: 34°7′N., 138°0′E., in 1003 metres; Brit. Mus.).—L. Döderlein, 1911, Abh. K. Bayer. Akad. Wiss., Math.-Phys. Abt., Suppl. vol. 1, p. 61, pl. 6, f. 4–4a, pl. 7, f. 13. (Suruga Bay, in 80 metres; Coll. L. Döderlein; Strassburg Mus.)

Materials: Two specimens. Diameter of disc 5 to 8 mm.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 60302).

Station 48: off Katu-ura, 13–15 metres. (Reg. No. 60303).

Distribution: Timor (R. Koehler): Philippines (R. Koehler): Japan; Eastern Sea (H. L. Clark), Yensyû Sea (Th. Lyman), off Omai-zaki (H. L. Clark), Suruga Bay (L. Döderlein, H. L. Clark), Sagami Bay (H. Matsumoto), Uraga Channel (H. Matsumoto).

Range in depth: 13–1003 metres.

Genus *Asteroporpa* C. F. Lütken, 1856

Asteroporpa C. F. Lütken, 1856, Vidensk. Meddel. fra den Naturh., p. 17.

Genohaplotype: *Asteroporpa annulata* Lütken, 1856, op. cit., p. 17. (West Indies, in 76 metres; Copenhagen Mus.)

Type by monotypy.

Asteroporpa hadracantha H. L. Clark, 1911

Asteroporpa hadracantha H. L. Clark, 1911, Bull. 75, U. S. National Mus., p. 280, f. 142. (Albatross Station 3764; holotype, off Suno-saki, in 67–76 metres; U. S. National Mus.; 3727, 3730, 4936, in Japan; Mus. Comp. Zool.).—H. Matsumoto, 1917, Journ. Coll. Sci., Imp. Univ. Tokyo, vol. 38, art. 2, p. 67, f. 17. (Sagami Bay, in 228–304 metres; Matsumoto Coll.; Inst. Geol. & Pal., Tôhoku Imp. Univ.)

Materials: Three specimens. Diameter of disc 6 to 7 mm.

Occurrence: Station 16: south of Ôsima. (Depth not given). (Reg. No. 60304).

Distribution: Japan; off Uzi-sima, Ôsumi (H. Matsumoto), Eastern Sea (H. L. Clark), off Omai-zaki (H. L. Clark), Sagami Bay (H. L. Clark, H. Matsumoto), off Suno-saki (H. L. Clark).

Range in depth: 52–156 metres.

Genus *Astrodendrum* L. Döderlein, 1911

Astrodendrum L. Döderlein, 1911, Abh. K. Bayer. Akad. Wiss., Math.-Phys. Abt., Suppl. vol. 1, p. 38.

Genorthotype: *Gorgonocephalus sagaminus* L. Döderlein, 1902, Zool. Anz., vol. 25, p. 321. (Sagami Bay; Coll. Haberer; München Mus.)

Type by original designation.

Astrodendrum sagaminum (L. Döderlein, 1902) L. Döderlein, 1911

Astrodendrum sagaminum (L. Döderlein) L. Döderlein, 1911, Abh. K. Bayer. Akad. Wiss., Math.-Phys. Abt., Suppl. vol. 1, p. 38, pl. 2, f. 3–5, pl. 7, f. 8. (Sagami Bay; Coll. Haberer; München Mus.)
Gorgonocephalus sagaminus L. Döderlein, 1902, Zool. Anz., vol. 25, p. 321. (Ibid.).

Material: One specimen. Diameter of disc 16 mm.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 60305).

Distribution: Indian Ocean (Bomford): Japan; Eastern Sea (H. L. Clark), Suruga Bay (H. L. Clark), Sagami Bay (L. Döderlein), Misaki (H. Matsumoto), Sea of Japan (H. L. Clark).

Range in depth: 90–304 metres.

Genus *Euryale* J. Lamarck, 1816

Euryale J. Lamarck, 1816, Hist. Nat. Anim. sans Vert., 2, p. 535.

Genotautotype: *Euryale verrucosum* Lamarck, 1816, op. cit., p. 535. (la mer des Indes et la mer du nord; Paris Mus.) = *Asterias euryale* Retzius, 1783, K. Vet.-Akad. Handl., vol. 4, p. 243.

Type by absolute tautonomy; or subsequent designation (*Astrophyton scutatum* Linck, 1733. = *E. verrucosum*) by Th. Wright, 1866, Monogr. Brit. Foss. Echinod. Oolit. Form., p. 132. (non *E. asperum* Lamarck, 1816, op. cit., p. 538, virtually selected by Th. Lyman, 1879, Bull. Mus. Comp. Zool., vol. 6, p. 60. fide H. L. Clark).

Typonym. Genus *Astrocladus* A. E. Verrill, 1899.

Astrocladus A. E. Verrill, 1899, Trans. Connect. Acad., vol. 10, p. 369.

Genorthotype: *Euryale verrucosum* Lamarck, 1816, op. cit., p. 535. (Loc. cit.)

Type by original designation.

Euryale dofleini (L. Döderlein, 1911) comb. nov.

Astrocladus dofleini L. Döderlein, 1911, Abh. K. Bayer. Akad. Wiss., Math.-Phys. Abt., Suppl. vol. 1, p. 41, textf. 9, pl. 2, f. 6, pl. 3, f. 1–4, pl. 4, f. 4, 5, pl. 7, f. 15. (Sagami Bay; Vladivostok; Coll. Doflein; München Mus.): L. Döderlein, 1927, Abh. K. Bayer. Akad. Wiss., Math.-Phys. Abt., vol. 31, pt. 6, pp. 35, 94, pl. 3, f. 2–2a. (Albatross Station 5483: Cabugan Grande Island, 10°27′30″N., 125°19′15″E., 112 metres; U. S. Nat. Mus.)

Materials: One complete specimen, diameter of disc 21 mm.; and one fractured specimen.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 60306).

Distribution: South India (Bomford): Philippines (L. Döderlein): Japan; Suruga Bay (L. Döderlein), Sagami Bay (L. Döderlein), Onahama Bay, Sea of Japan (L. Döderlein): Vladivostok (L. Döderlein).

Range in depth: 52–222 metres.

Genus *Amphiura* E. Forbes, 1843

Amphiura E. Forbes, 1843, Trans. Linn. Soc. London, vol. 19, p. 149.

Genologotype: *Amphiura chiajii* Forbes, 1843, op. cit., p. 151, pl. 14, f. 14–18. (Aegean Archipelago, Coast of Asia Minor, in 15–182 metres; Brit. Mus.?).

Type by subsequent designation by A. E. Verrill, 1899, Bull. Univ. Iowa, new ser., vol. 1, no. 6, p. 24.

Amphiura diomedeae C. F. Lütken et Th. Mortensen, 1899

Amphiura diomedeae C. F. Lütken and Th. Mortensen, 1899, Mem. Mus. Comp. Zool., Harvard College, vol. 2, p. 151, pl. 12, f. 1–7. (Albatross Station 3393: Gulf of Panama, in 1550 metres; Cotype in Mus. Comp. Zool.).—R. Koehler, 1922, Bull. 100, U. S. National Mus., vol. 5, p. 158, pl. 67, f. 7–10. (Albatross Stations, 5111, 5281, 5325, 5535, 368–567 metres; U. S. National Mus.)

Material: One specimen, diameter of disc 5 mm.

Occurrence: Station 26: off Kuriyama-gawa, 21 metres. (Reg. No. 60307).

Distribution: China Sea (R. Koehler); Philippines (R. Koehler): Japan; Kagosima Bay (H. L. Clark), off Eastern Japan

(H. L. Clark), Suruga Bay (H. L. Clark), off Omai-zaki (H. L. Clark), Sagami Bay (H. L. Clark, H. Matsumoto), Sea of Japan (H. L. Clark): California (H. L. Clark): Gulf of Panama (C. Lütken).

Range in depth: 20–1550 metres.

Genus *Ophionephthys* C. F. Lütken, 1869

Ophionephthys C. F. Lütken, 1869, Addit. ad Hist. Oph., 3, pp. 25, 93.

Genohaplotype: *Ophionephthys limicola* Lütken, 1869, op. cit., pp. 24, 25, (West Indies, in 76 metres; Cotype in Mus. Comp. Zool.).

Type by monotypy.

Ophionephthys vadicola (H. Matsumoto, 1915) H. L. Clark, 1918

Ophionephthys vadicola (H. Matsumoto) H. L. Clark, 1918, Bull. Mus. Comp. Zool., Harvard College, vol. 62, p. 281. (No authentic specimens).

Amphiura vadicola H. Matsumoto, 1915, Proc. Acad. Nat. Sci. Philadelphia, vol. 67, p. 71. (Sakura-zima, Kagosima Bay; Paratypes? in Inst. Geol. & Pal., Tôhoku Imp. Univ.).—R. Koehler, 1922, Bull. 100, U. S. National Mus., vol. 5, p. 161, pl. 65, f. 1–5, pl. 96, f. 5. (Otaru, Hokkaidô; Albatross Coll.; U. S. National Mus.)

Material: One specimen, diameter of disc 4 mm.

Occurrence: Station 14: off Inubô-zaki, 26 metres. (Reg. No. 60308).

Distribution: Japan; Kagosima Bay (H. Matsumoto); Tintô, Tyôsen (H. Matsumoto), off Tone-gawa, Otaru, Hokkaidô (R. Koehler).

Range in depth: Littoral—sublittoral.

Genus *Ophiothrix* J. Müller et F. Troschel, 1840

Ophiothrix J. Müller and F. Troschel, 1840, Archiv für Naturg., vol. 6, p. 328.

Genologotype: *Ophiura rosula* E. Fleming, 1828, Brit. Anim., p. 489. (British Sea) = *Asterias pentaphylla* Th. Pennant, 1777, Brit. Zool., vol. 4, p. 64. (South of England).

Type by subsequent designation by Th. Lyman, 1865, Mem. Mus. Comp. Zool., vol. 1, p. 153.

Ophiothrix koreana P. M. Duncan, 1879

Ophiothrix koreana P. M. Duncan, 1879, Journ. Linn. Soc. London, Zool., vol. 14, p. 473, pl. 11, f. 28–32. (Korea Strait, in 35 metres; W. P. Sladen Coll.; Brit. Mus.).—R. Koehler, 1922, Bull. 100, U. S. National Mus., vol. 5, p. 242, pl. 45, f. 1–6, pl. 99, f. 4. (Albatross Stations, 5116, 5135, 5179, 5187, 5212, 5213, 5221, 5257, 5265, 5373, 5391, 5392, 5420, in 51–618 metres; U. S. National Mus.).

Materials: Ten specimens. Diameter of disc, 6 to 10 mm.

Occurrence: Station 5: off Mera. (Depth not given). (Reg. No. 60309).

Station 23: off Iioka, 12 metres. (Reg. No. 60310).

Distribution: Molucca (Marktanner-Turneretscher): Philippines (R. Koehler): Japan; off Satuma (H. L. Clark), Kagosima Bay (H. L. Clark), Korea Strait (P. M. Duncan), Suruga Bay (H. L. Clark), Eastern Japan (H. L. Clark), Sagami Bay (H. L. Clark, H. Matsumoto), Uraga Channel (H. L. Clark, H. Matsumoto), off Kazusa, Hakodate Bay (H. L. Clark), Sea of Japan (H. L. Clark).

Range in depth: 10–618 metres.

Ophiothrix marenzelleri R. Koehler, 1904

Ophiothrix marenzelleri R. Koehler, 1904, Mém. Soc. Zool. France, vol. 17, p. 103, textf. 76–78. (Japan; Marenzeller Coll.; Paris Mus. ex Vienna Mus.): R. Koehler, 1922, Bull. 100, U. S. National Mus., vol. 5, p. 248, pl. 39, f. 3–5, pl. 100, f. 4. (Enosima, Sagami Bay; Albatross Coll.; U. S. National Mus.)

Materials: Ten specimens. Diameter of disc, 3 to 10 mm.

Occurrence: Station 24: off Iioka, 24 metres. (Reg. No. 60311).

Station 42: off Itinomiya, 15.4 metres. (Reg. No. 60312).

Distribution: Japan; Kagosima Bay (H. Matsumoto), Asami Bay (H. Matsumoto), Toba, Sima (H. Matsumoto), Tomo, Bingo (H. Matsumoto), Sagami Bay (H. Matsumoto, R. Koehler), Tokyo Bay (H. Matsumoto), Kominato, Bosyû (H. Matsumoto), Ayukawa (H. L. Clark).

Range in depth: Littoral to sublittoral.

Ophiothrix eusteira H. L. Clark, 1911

Ophiothrix eusteira H. L. Clark, 1911, Bull. 75, U. S. National Mus.,

p. 265, f. 132, (Amami-Ôsima; Coll. W. Stimpson; U. S. National Mus.).—H. Matsumoto, 1917, Journ. Coll. Sci., Imp. Univ. Tokyo, vol. 38, art. 2, p. 222, f. 60. (Sagami Bay, in 114 metres; Matsumoto Coll.; Inst. Geol. & Palaeont., Tôhoku Imp. Univ.)

Materials: Three specimens. Diameter of disc 5 to 7 mm.

Occurrence: Station 26: off Kuriyama-gawa, 21 metres. (Reg. No. 60313).

Station 45: off Ôhara, 130.5 metres. (Reg. No. 60314).

Distribution. Amami-Ôsima (H. L. Clark); Pinnacle Islands (H. Matsumoto); Sagami Bay (H. Matsumoto), Uraga Channel (H. Matsumoto), Kominato, Bosyû (H. Matsumoto).

Range in depth: 0–114 metres.

Genus *Ophiogymna* A. v. Ljungman, 1886

Ophiogymna A. v. Ljungman, 1886, Ofv. Kongl. Vet.-Akad. Forh., vol. 32, p. 163.

Genohaplotype: *Ophiogymna elegans* Ljungman, 1886, op. cit., p. 163. (Singapore; littoral; Stockholm Mus.)

Type by monotypy.

Ophiogymna fulgens (R. Koehler, 1905) R. Koehler, 1922

Ophiogymna fulgens (R. Koehler) R. Koehler, 1922, Bull. 100, U. S. Nat. Mus., vol. 5, p. 228, pl. 42, f. 3–8, pl. 43, f. 9, 10, pl. 44, f. 8, pl. 60, f. 6, pl. 103, f. 8. (Albatross Stations, 4935, 4948, 5070, 5080, 5117, 5138, 5141, 5255, 5393, 5413, 5414, 5519, 5545, 35–923 metres; U. S. Nat. Mus.)

Ophiothrix fulgens R. Koehler, 1905, Siboga-Exp., vol. 45, Oph. litt., p. 107, pl. 10, f. 3–6. (Siboga Station 260: 5°36′.5N., 132°55′.2E.; in 90 metres; Amsterdam Mus.)

Materials: Two specimens. Diameter of disc 4 to 6 mm.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 60315).

Distribution: South Sea Islands (R. Koehler): Philippines (R. Koehler): Japan; off Kagosima Bay (R. Koehler), off Ôsima Light House (R. Koehler), Suruga Bay (R. Koehler), off Omai-zaki Light (R. Koehler), off Kazusa (S. Nisiyama).

Range in depth: 35–923 metres.

Genus *Stegophiura* H. Matsumoto, 1915

Stegophiura H. Matsumoto, 1915, Proc. Acad. Nat. Sci. Philadelphia, vol. 67, p. 78.

Genorthotype: *Ophiura nodosa* C. F. Lütken, 1855, Vidensk. Meddel., Forh., 1855, p. 100. (Greenland; littoral; Copenhagen Mus.)

Type by original designation.

Stegophiura sladeni (P. M. Duncan, 1879) H. Matsumoto, 1915

Stegophiura sladeni (P. M. Duncan) H. Matsumoto, 1915, Proc. Acad. Nat. Sci. Philadelphia, vol. 67, p. 79. (Nominal).—R. Koehler, 1922, Bull. 100, U. S. National Mus., vol. 5, p. 369, pl. 83, f. 4–7. pl. 84, f. 1. (Hakodate, Hokkaidô; Albatross Coll.; U. S. National Mus.)

Ophioglypha sladeni P. M. Duncan, 1879, Journ. Linn, Soc. London, Zool., vol. 14, p. 458, pl. 9, f. 9–11. (Korean coast; Coll. W. P. Sladen; Brit. Mus.)

Materials: Eighty-seven specimens. Diameter of disc 11 to 16 mm.

Occurrence: Station 22: off Nagasaki-hana, 35 metres. (Reg. No. 60316).

Station 25: off Iioka, 39 metres. (Reg. No. 60317).

Station 39: off Itinomiya, 44 metres. (Reg. No. 60318).

Distribution: Japan; off Kagosima Bay (H. L. Clark), Korean coast (P. M. Duncan), Suruga Bay (H. L. Clark), Sagami Bay (H. L. Clark, H. Matsumoto), Uraga Channel (H. Matsumoto), off Kazusa, off Kinkazan (H. Matsumoto), Sea of Japan (H. L. Clark), Hakodate (R. Koehler).

Range in depth: 20–240 metres.

Genus *Ophiomusium* Th. Lyman, 1869

Ophiomusium Th. Lyman, 1869, Bull. Mus. Comp. Zool., Harvard College, vol. 1, p. 322.

Genohaplotype: *Ophiomusium eburneum* Th. Lyman, 1869, op. cit., p. 322. (West of Sand Key, Florida, in 395 metres; Coll. L. F. de Pourtales; Cotype in Mus. Comp. Zool., & U. S. National Mus.)

Type by monotypy.

Ophiomusium trychnum H. L. Clark, 1911

Ophiomusium trychnum H. L. Clark, 1911, Bull. 75, U. S. National

Mus., p. 109, f. 40. (Holotype; Albatross Station 5069, Suruga Bay, 35°3′10″N., 138°47′E., in 164–199 metres; U. S. National Mus.: Stations, 3661, 3704, 4959, 4965, 5091, 5092, 5093, 5094, in Japan; Mus. Comp. Zool.).—H. Matsumoto, 1917, Journ. Coll. Sci., Imp. Univ. Tokyo, vol. 38, art. 2, p. 290, f. 78. (Sagami Bay, 455 metres; Matsumoto Coll. ex K. Aoki; Inst. Geol. & Pal., Tôhoku Imp. Univ.).

Materials: Two specimens. Diameter of disc 10 to 12 mm.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 60319).

Distribution: Japan; Suruga Bay (H. L. Clark), Sagami Bay (H. L. Clark, H. Matsumoto), Uraga Channel (H. L. Clark), Tokyo Bay (H. L. Clark), off Kazusa, off Eastern Japan (H. L. Clark).

Range in depth: 82–878 metres.

Ophiomusium cancellatum Th. Lyman, 1878.

Ophiomusium cancellatum Th. Lyman, 1878, Bull. Mus. Comp. Zool., Harvard College, vol. 5, p. 111, pl. 1, f. 17, 18. (Challenger Station 236: June 5, 1875; 34°58′N., 139°36′E., off Omai-zaki, in 638–1178 metres; Brit. Mus.).—H. Matsumoto, 1917, Journ. Coll. Sci., Imp. Univ. Tokyo, vol. 38, art. 2, p. 291. (Uraga Channel; depth unknown; Matsumoto Coll. ex J. Hara; Inst. Geol. & Pal., Tôhoku Imp. Univ.).

Material: One specimen, diameter of disc 14 mm.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 60320).

Distribution: Japan; Colnett Strait (H. L. Clark), off Heda (H. L. Clark), Bungo Channel (H. L. Clark), Suruga Bay (H. L. Clark), off Omai-zaki (Th. Lyman, H. L. Clark), Sagami Bay (H. L. Clark), Uraga Channel (H. L. Clark, H. Matsumoto), off Eastern Japan (H. L. Clark), off Kazusa (S. Nisiyama).

Range in depth: 90–1532? metres.

Annotated List of Echinoids dredged from the Pacific Coast of Tiba Prefecture*

By

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Sendai, Japan.

All the species enumerated in the following list were collected by the surveying ship Husa-maru of the Tiba Fisheries Experimental Station at Tateyama-Hôzyô-mati, Tiba prefecture during the years 1931–1933. Dredge operation and other oceanographical observations were carried out by the members of the Station under the direction of the Director Mr. K. Suganuma assisted by Mr. K. Nagami, in the shallow littoral sea along the Pacific coast of Bôsô Peninsula at a depth of less than 300 meters. The greater part of the material put at my disposal for specific determination through the kindness of the Staffs of the Station is now stored in the Institute of Geology and Palaeontology, Tôhoku Imperial University, Sendai, while the remaining part lies in the collection of the Station.

Very little has been previously known about the echinoid fauna of the Pacific coast of Tiba prefecture; of the present material of more than five hundred specimens of echinoids, more than eighteen species in sixteen genera are distinguished. None of them are new to science, however, some species are of much interest in respect of geographical distribution.

*) This article is a continuation of the reports on the material collected by the "Husa-Maru" of the Tiba Fisheries Experimental Station at Tateyama. The first article was by K. Okamura entitled, "Notes on Algae dredged from the Pacific Coast of Tiba Prefecture"; see Rec. Ocean. Wk. Jap., Vol. 6, No. 1, 1934. The second article was by K. Hatai entitled, "A List of the Recent Brachipoda Dredged from the Littoral Sea of the Pacific Side of Bôsô Peninsula, Central Japan"; see Rec. Ocean. Wk. Jap., Vol. 8, No. 1, 1936. The third article was by S. Nisiyama entitled, "Annotated List of the Ophiurians dredged from the Pacific Coast of Tiba Prefecture"; see Rec. Ocean. Wk. Jap., Vol. 9, No. 1, 1937. The present article is the fourth on the material collected by the Tiba Fisheries Experimental Station.

The species here enumerated are eighteen in number and are those identified with confidence. Besides the specifically determined forms, there are also several others which are either indeterminable or doubtfully identified; these are not included in the present list. Of the eighteen species listed, three belong to Cidaroida, seven to Centrechinoida (Diadematoida) and eight to Exocycloida.

At this place I wish to offer my warmest thanks to the Staffs of the Station, especially to the Director, Mr. K. Suganuma for his kind offer of the material to my study, to Mr. K. Nagami for information concerning the dredge operation and other necessary oceanographical data, and to Mr. Takehara for his kind assistance and warm hospitality given me during my visit to that Station. Special thanks are due to Prof. H. Yabe of the Institute of Geology and Palaeontology, Tôhoku Imperial University, under whose direction I am now studying the fossil and recent echinoids of Japan, for his constant help and encouragement.

Genus *Stereocidaris* N. A. Pomel, 1883

Stereocidaris N. A. Pomel, 1883, Thèses....Class. méthod. Gen. Ech., p. 110.

Genologotype: *Cidaris cretosa* G. Mantell, 1822, Geol. of Sussex, p. 194, pl. 17, f. 13. (J. Parkinson, 1811, Organic Remains, vol. 3, p. 13, pl. 1, f. 11: Upper chalk of Kent, Sussex.)

Type by subsequent designation by H. L. Clark, 1907, Bull. Mus. Comp. Zool., Harvard College, vol. 51, p. 177.

Subgenus *Phalacrocidaris* J. Lambert, 1902

Phalacrocidaris J. Lambert, 1902, Mém. Soc. Géol. France, vol. 24, Paléont., 14, p. 26.

Orthotype: *Dorocidaris japonica* L. Döderlein, 1885, Archiv für Naturg., vol. 51(1), p. 76. (Sagami Bay, in 180–290 metres; Coll. L. Döderlein; Strassburg Mus.)

Type by original designation.

Stereocidaris (*Phalacrocidaris*) *japonica* (L. Döderlein, 1885) L. Döderlein, 1887

Stereocidaris japonica (Döderlein) L. Döderlein, 1887, Jap. Seeigel, 1, pp. 6, 42, pl. 3, f. 1–20, pl. 8, f. 1a–h. (Sagami Bay, in 180–290 metres and coast of Tango, in 72 metres; Coll. L. Döderlein; Strass-

burg Mus.)

Dorocidaris japonica L. Döderlein, 1885, Archiv für Naturg., vol. 51 (1), p. 76. (ibid.)

Materials: Thirty-five specimens, 11 to 30 mm. in diameter.

Occurrence: Station 40: off Itinomiya, 13 metres. (Reg. No. 58302).[1)]

Station 6: off Mera. (Depth not given). (Reg. No. 58303).

Distribution: Japan; Eastern Channel (H. L. Clark, Th. Mortensen), Sagami Bay (Döderlein, H. L. Clark), Tango (Döderlein), Sea of Japan (H. L. Clark, Th. Mortensen), Tugaru Strait (H. L. Clark).

Range in depth: 13–300 metres.

Genus *Goniocidaris* L. Agassiz et E. Desor, 1846

Goniocidaris L. Agassiz and E. Desor, 1846, Ann. Sci. Nat., Zool., ser. 3, vol. 6, p. 337.

Genorthotype: *Cidaris geranioides* J. Lamarck, 1816, Hist. Nat. Anim. sans Vert., vol. 3, p. 56. (East Indian Sea; Coll. ?; Paris Mus.)

Type by original designation.

Subgenus *Discocidaris* L. Döderlein, 1885

Discocidaris L. Döderlein, 1885, Archiv für Naturg., vol. 51(1), p. 80.

Haplotype: *Discocidaris* (*Cidaris*) *mikado* L. Döderlein, 1885, op. cit., p. 80. (Sagami Bay, in 290 metres; Coll. L. Döderlein; Strassburg Mus.)

Type by monotypy.

Goniocidaris (*Discocidaris*) *mikado* (L. Döderlein, 1885) L. Döderlein, 1887

Goniocidaris mikado (Döderlein) L. Döderlein, 1887, Jap. Seeigel, 1, p. 15, pl. 7, f. 1–6, pl. 8, f. 6a–f. (Sagami Bay, in 290 metres; Coll. L. Döderlein; Strassburg Mus.)

Discocidaris mikado L. Döderlein, 1885, Archiv für Naturg., vol. 51 (1), p. 80. (ibid.)

Materials: Two specimens, 10 and 21 mm. in diameter.

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1) Register number of specimens in the collection of the Institute of Geology and Palaeontology, Tôhoku Imperial University, Sendai.

Occurrence: Station 5: off Mera. (Depth not given). (Reg. No. 58304).

Station 16: south of Ôsima. (Depth not given). (Reg. No. 58305).

Distribution: Japan; southwest of Gotô Islands (H. L. Clark), Suruga Bay (H. L. Clark), Sagami Bay (Döderlein, Th. Mortensen).

Range in depth: 80–290 metres.

Goniocidaris (*Discocidaris*) *clypeata* L. Döderlein, 1885

Goniocidaris clypeata L. Döderlein, 1885, Archiv für Naturg., vol. 51 (1), p. 82. (Sagami Bay, in 360 metres; Coll. L. Döderlein; Strassburg Mus.): L. Döderlein, 1887, Jap. Seeigel, 1, p. 16, pl. 4, f. 8–20, pl. 6. (ibid.)

Materials: Two specimens, 12 and 18 mm. in diameter, and radioles.

Occurrence: Station 40: off Itinomiya, 13 metres. (Reg. No. 58307).

Station 44: off Taitô-zaki, 104 metres. (Reg. No. 58306).

Station 85: off Wada, 130–147 metres. (Reg. No. 58308).

Distribution: Japan; Kagosima Bay (H. L. Clark), southwest of Gotô Islands (H. L. Clark), Sagami Bay (Döderlein, Th. Mortensen), Uraga Channel (H. L. Clark).

Range in depth: 13–360 metres.

Genus *Coenopedina* Al. Agassiz, 1869

Coenopedina Al. Agassiz, 1869, Bull. Mus. Comp. Zool., Harvard College, vol. 1, p. 256.

Genohaplotype: *Coenopedina cubensis* Al. Agassiz, 1869, op. cit., p. 256. (Off Cuba, in 248–486 metres; P. de Pourtales Coll.; Mus. Comp. Zool.)

Type by monotypy.

Coenopedina mirabilis (L. Döderlein, 1885)
Th. Mortensen, 1904

Coenopedina mirabilis (Döderlein) Th. Mortensen, 1904, Kongl. Dansk. Vidensk. Selsk. Skr., 7 ser., vol. 1, p. 34. (Examined the

type).—H. L. Clark, 1912, Mem. Mus. Comp. Zool., Harvard College, vol. 34, p. 221, pl. 91, f. 14–17, pl. 105, f. 8. (Albatross Stations, 3708, 4807, 4808, 4900, 4933, 4934, 4965, 5047; from Japan, in 80–344 metres; Mus. Comp. Zool.)

Hemipedina mirabilis L. Döderlein, 1885, Archiv für Naturg., vol. 51 (1), p. 96. (Sagami Bay, in 360 metres; Coll. L. Döderlein; Strassburg Mus.)

Materials: Five specimens, 8 to 12 mm. in diameter.

Occurrence: Station 24: off Iioka, 24 metres. (Reg. No. 58309). Station 26: off Kuriyama-gawa, 21 metres. (Reg. No. 58310).

Distribution: Japan; off Kagosima Bay (H. L. Clark), off Hiro-Misaki Light House (H. L. Clark), off Ose-Zaki (H. L. Clark, Th. Mortensen), Sagami Bay (Döderlein, Th. Mortensen), off Kinkazan Light House (H. L. Clark), Tugaru Strait (H. L. Clark).

Range in depth: 21–360 metres.

Genus *Glyptocidaris* Al. Agassiz, 1863

Glyptocidaris Al. Agassiz, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 356.

Genohaplotype: *Glyptocidaris crenularis* Al. Agassiz, 1863, op. cit., p. 356. (Hakodate Bay; W. Stimpson Coll.; Mus. Comp. Zool.)

Type by monotypy.

Glyptocidaris crenularis Al. Agassiz, 1863

Glyptocidaris crenularis Al. Agassiz, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 356. (loc. cit.).—H. L. Clark, 1912, Mem. Mus. Comp. Zool., Harvard College, vol. 34, p. 228, pl. 90, f. 5–10, pl. 92, f. 1–11, pl. 106, f. 1, 2. (Albatross Stations, 4807, 5046, in 80–158 metres; Mus. Comp. Zool.)

Materials: One specimen, 35 mm. in diameter, and a fractured test.

Occurrence: Station 16: off Inubô-zaki, 42 metres. (Reg. No. 58311).

Distribution: Japan; off Tyôsi!, Onahama Bay, Sendai Bay, off Kinkazan Light House (H. L. Clark), Mutu Bay (Th. Mortensen), Tugaru Strait (H. L. Clark), Hakodate Bay (Al. Agassiz, Döderlein).

Range in depth: 0–158 metres.

Genus *Opechinus* E. Desor, 1856

Opechinus E. Desor, 1856, Synop. Ech. Foss., 2 & 3, p. 107.

Genologotype: *Temnopleurus rousseausi* A. d'Archiac and J. Haime, 1853, Descr. Anim. Foss. Numm. Ind., p. 205, pl. 13, f. 10. (Kachh., Ind.; Miocene; Mus. Geol. Soc. London ex d'Archiac.)

Type by subsequent designation by J. Lambert and P. Thiéry, 1911, Ess. nomencl. rais. Ech., 3, p. 232.

Opechinus variabilis (L. Döderlein, 1885) Th. Mortensen, 1904

Opechinus variabilis (Döderlein) Th. Mortensen, 1904, Dansk. Kongl. Vidensk. Selsk. Skr., 7 ser., vol. 1, pp. 92, 94, pl. 6, f. 27, pl. 7, f. 2. (Pedicellariae of the type figured).

Pleurechinus variabilis L. Döderlein, 1885, Archiv für Naturg., vol. 51 (1), p. 93. (Sagami Bay, in 182–270 metres; Coll. Döderlein; Strassburg Mus.): L. Döderlein, 1903, Jena. Denkschr., vol. 8, p. 706, pl. 61, f. 4. (ibid.: Type figured.)

Materials: Four bare tests, 12 to 15 mm. in diameter.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 58316).

Station 85: off Wada, 130–147 metres. (Reg. No. 58317).

Distribution: Japan; southwest of Gotô Islands (H. L. Clark), Suruga Bay (H. L. Clark), Sagami Bay (Döderlein).

Range in depth: 65–270 metres.

Genus *Temnopleurus* L. Agassiz, 1841

Temnopleurus L. Agassiz, 1841, Monogr. Ech., Anat. Echinus, p. vii.

Genohaplotype: *Cidaris toreumatica* N. G. Leske, 1778, Addit. ad Klein nat. Disposit. Ech., p. 155. (Indian Ocean; no longer in the Dresden Mus. ?)

Type by monotypy.

Temnopleurus hardwickii (J. E. Gray, 1855) Al. Agassiz, 1872

Temnopleurus hardwickii (J. E. Gray) Al. Agassiz, 1872, Mem. Mus. Comp. Zool., Harvard College, vol. 3, pp. 166, 460, pl. 8 a, f. 1–3. (N. E. end of Japan; W. Stimpson Coll.; Mus. Comp. Zool.).— Th. Mortensen, 1904, Dansk. Vidensk. Selsk. Skr., 7 ser., vol. 1,

pp. 61, 65, pl. 6, f. 32, 34, pl. 7, f. 21. (Examined the types of *T. hardwickii* and *T. japonicus* VON MARTENS): TH. MORTENSEN, 1929, Sci. Rep. Tôhoku Imp. Univ., 4th ser., vol. 4, p. 473, pl. 19, f. 3. (Mutu Bay; Coll. S.S. Sôyô-Maru; Copenhagen Mus.)

Toreumatica hardwickii J. E. GRAY, 1855, Proc. Zool. Soc. London, vol. 23, p. 39. (Hab. ?; Brit. Mus. ? ex HARDWICKE).

Materials: Sixteen specimens, 13 to 36 mm. in diameter.

Occurrence: Station 24: off Iioka, 24 metres. (Reg. No. 58313).
Station 25: off Iioka, 39 metres. (Reg. No. 58314).

Distribution: Japan; off Yokohama (CHALLENGER), Tokyo Bay (H. L. CLARK), Sendai Bay (H. L. CLARK), Mutu Bay (TH. MORTENSEN), Tugaru Strait (H. L. CLARK).

Range in depth: 0–40 metres.

Genus *Temnotrema* AL. AGASSIZ, 1863

Temnotrema AL. AGASSIZ, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 358.

Genohaplotype: *Temnotrema sculptum* AL. AGASSIZ, 1863, op. cit., p. 358. (Kagosima Bay; W. STIMPSON Coll.; Mus. Comp. Zool.)

Type by monotypy.

Temnotrema sculptum AL. AGASSIZ, 1863

Temnotrema sculptum AL. AGASSIZ, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 358. (Kagosima Bay; W. STIMPSON Coll.; Mus. Comp. Zool.).—H. L. CLARK, 1912, Mem. Mus. Comp. Zool., Harvard College, vol. 34, p. 321, pl. 112, f. 1, 2. (Type figured: Albatross Stations, 4893, 4895, 5095, in 86–182 metres; Mus. Comp. Zool.).—SY. NISIYAMA, 1936, Journ. Geol. Soc. Japan, vol. 43, p. 121, pl. 11, f. 10–16. (Husa-Maru Station 24; reproductions of H. L. CLARK's figures and *Pleurechinus variegatus* MORTENSEN).

Material: One specimen, 16 mm. in diameter.

Occurrence: Station 24: off Iioka, 24 metres. (Reg. No. 58318).

Distribution: Torres Strait (H. L. CLARK): Formosan Channel (TH. MORTENSEN): Japan; southwest of Gotô Islands (H. L. CLARK), off Kôbe (CHALLENGER), Sagami Bay (TH. MORTENSEN), off Kazusa (NISIYAMA), Mutu Bay (TH. MORTENSEN).

Range in depth: 12–264 metres.

Temnotrema rubrum (L. Döderlein, 1885) H. L. Clark, 1912

Temnotrema rubrum (L. Döderlein) H. L. Clark, 1912, Mem. Mus. Comp. Zool., Harvard College, vol. 34, p. 319. (Asynonym. nominal.). —Sy. Nisiyama, 1936, Journ. Geol. Soc. Japan, vol. 43, p. 125, pl. 11, f. 4–9. (Husa-Maru Station 51; reproduction of Döderlein's original figures).

Pleurechinus ruber L. Döderlein, 1885, Archiv für Naturg., vol. 51 (1), p. 20. ('Kadsiyama', in Tokyo Bay, in 36 metres; Coll. L. Döderlein; Strassburg Mus.) : L. Döderlein, 1903, Jena. Denkschr., vol. 8, p. 706, pl. 61, f. 3. (Ibid.; type figured).

Material: One specimen, 20 mm. in diameter.

Occurrence: Station 51: off Ubara, 5 metres. (Reg. No. 58319).

Distribution: Japan; Tokyo Bay (L. Döderlein), off Ubara (Nisiyama).

Range in depth: 5–36 metres.

Genus *Strongylocentrotus* J. F. Brandt, 1835

Strongylocentrotus J. F. Brandt, 1835, Prodr. Descr. Anim., p. 265.

Genohaplotype: *Strongylocentrotus chlorocentrotus* Brandt, 1835, op. cit., p. 265. (Sitka Island, Alaska?; Mertens Coll.; Zool. Mus. in Acad. Sci. Leningrad?).=*Echinus droebachiensis* O. F. Müller, 1776, Prodr. Zool. Dan., p. 235, no. 2846. (Dröbak, south of Oslo, Norway).

Type by monotypy.

Strongylocentrotus nudus (Al. Agassiz, 1863) Al. Agassiz 1872

Strongylocentrotus nudus (Al. Agassiz) Al. Agassiz, 1872, Mem. Mus. Comp. Zool., Harvard College, vol. 3, pp. 165, 448, pl. 24 t, f. 26–30. (N. E. end of Japan; W. Stimpson Coll.; Mus. Comp. Zool.),— Th. Mortensen, 1929, Sci. Rep. Tôhoku Imp. Univ., 4th ser., vol. 4, p. 476, textf. 1, pl. 19, f. 2. (Mutu Bay; S. Hôzawa Coll.; Copenhagen Mus.).

Toxocidaris nuda Al. Agassiz, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 356. (N. E. end of Japan; W. Stimpson Coll.; Mus. Comp. Zool.)

Material: One specimen, 18 mm. in diameter.

Occurrence: Station 42: off Itinomiya, 15.4 metres. (Reg. No. 58320).

Distribution: Japan; Sagami Bay (L. Döderlein), off Kazusa,

Onahama Bay, Sendai Bay, off Kinkazan Light House (H. L. Clark), Mutu Bay (Th. Mortensen), Hakodate Bay (L. Döderlein).

Range in depth: 0–180 metres.

Genus *Fibularia* J. Lamarck, 1816

Fibularia J. Lamarck, 1816, Hist. Nat. Anim. sans Vert., 3, p. 16.

Genologotype: *Fibularia trigona* Lamarck, 1816, op. cit., p. 16. (Indian Ocean?; Paris Mus.) = *Echinocyamus craniolaris* N. G. Leske, 1778, Addit. ad Klein nat. Disposit. Ech., p. 150. (Indian Ocean?; no longer in the Museum of Cramer.).

Type by subsequent designation by L. Agassiz and E. Desor, 1847, Ann. Sci. Nat., Zool., ser. 3, vol. 7, p. 142.

Fibularia acuta Sh. Yoshiwara, 1898

Fibularia acuta Sh. Yoshiwara, 1898, Annot. Zool. Japan., vol. 2, p. 60. (Misaki, and Sigazima; Zool. Inst., Imp. Univ. Tokyo,).—H. L. Clark, 1914, Mem. Mus. Comp. Zool., Harvard College, vol. 46, p. 58, pl. 126, f. 1–4. (Asamiwan, Tusima; presented by Dr. S. Gotô; Mus. Comp. Zool.).

Material: One specimen, 7 mm. in longitudinal diameter.

Occurrence: Station 44: off Taitô-zaki, 104 metres. (Reg. No. 58321).

Distribution: Japan; Kyûsyû (Yoshiwara), Tusima (Yoshiwara), Sagami Bay (Yoshiwara), off Kazusa, Sendai Bay, off Miyako, Rikutyû (S. Nomura).

Range in depth: 0–80 metres.

Genus *Laganum* J. E. Gray, 1825

Laganum J. E. Gray, 1825, Annal. Philos., vol. 26, (n.s. vol. 10), p. 427. (Lagana by error).

Genotautotype: *Lagana minor* Gray, 1825, op. cit., p. 427. (New Guinea; Coll. Quoy) = *Echinodiscus laganum* N. Leske, 1778, Addit. ad Klein nat. Disposit. Ech., p. 140, pl. 22, f. c. (Indian Ocean?; Dresden Mus.?).

Type by absolute tautonomy.

Laganum fudsiyama L. Döderlein, 1885

Laganum fudsiyama L. Döderlein, 1885, Archiv für Naturg., vol. 51

(1), p. 104. (Sagami Bay, in 182–304 metres; Coll. Döderlein; Strassburg Mus.).—H. L. Clark, 1914, Mem. Mus. Comp. Zool., Harvard College, vol. 46, p. 46, pl. 140, f. 3, 4, pl. 141, f. 4–9. (Albatross Stations, 4080, 4081, 4965, 5091; Japan and Hawaiian Islands, in 44–465 metres; Mus. Comp. Zool.).

Material: One bare specimen, 25 mm. in longitudinal diameter.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 58322).

Distribution: Fiji Islands (Challenger); Japan; off Seno-umi (H. L. Clark), Sagami Bay (L. Döderlein), off Suno-saki (H. L. Clark), Tokyo Bay (H. L. Clark), off Kazusa; Hawaiian Islands (H. L. Clark).

Range in depth: 43–524 metres.

Laganum diploporum Al. Agassiz et H. L. Clark, 1907

Laganum diploporum Al. Agassiz and H. L. Clark, 1907, Bull. Mus. Comp. Zool., Harvard College, vol. 51, p. 129. (Albatross Stations, 3707, 3748, 4885, 4888, 4893, 4895, 4902, 4904, 4933, 4934, 5055, 5070, 5092, in 80–304 metres; Japan; Mus. Comp. Zool.).—H. L. Clark, 1914, Mem. Mus. Comp. Zool., Harvard College, vol. 46, p. 48, pl. 127, f. 9–12, pl. 142, f. 2–4. (Ibid.; lectotype; Albatross Station 3707, off Ose-zaki, in 95–114 metres; Mus. Comp. Zool.).

Material: One bare test, 28 mm. in longitudinal diameter.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 58323).

Distribution: Japan; Kagosima Bay (H. L. Clark), southwest of Gotô Islands (H. L. Clark), near Nagasaki (H. L. Clark), off Ose-zaki (H. L. Clark), Suruga Bay (H. L. Clark), off Suno-saki (H. L. Clark), Tokyo Bay (H. L. Clark), off Kazusa.

Range in depth: 80–304 metres.

Genus *Peronella* J. E. Gray, 1855

Peronella J. E. Gray, 1855, Cat. Rec. Ech. Brit. Mus., 1, p. 13. (Subgenus).

Genohaplotype: *Laganum peronii* L. Agassiz, 1841, Monogr. Ech., Monogr. Scut., p. 123, pl. 22, f. 7, 10, 21, 24. (South Sea; Coll. Péron; Paris Mus.).

Type by monotypy at the time.

Peronella rubra L. Döderlein, 1885

Peronella rubra L. Döderlein, 1885, Archiv für Naturg., vol. 51 (1), p. 106. (Inland Sea (Setouti), in 38 metres; Coll. L. Döderlein; Strassburg Mus.).—H. L. Clark, 1914, Mem. Mus. Comp. Zool., Harvard College, vol. 46, p. 54, pl. 124, f. 18–20, pl. 142, f. 5–7. (Uraga Channel, 38 metres; Owston Coll.; Mus. Comp. Zool).

Materials: Five specimens, 18 to 43 mm. in longitudinal diameter.

Occurrence: Station 51: off Ubara, 5 metres. (Reg. No. 58324).

Distribution: Japan; Inland Sea (L. Döderlein), Sagami Bay (H. L. Clark), Uraga Channel, off Ubara, Mutu Bay (Th. Mortensen).

Range in depth: 5–60 metres.

Genus *Echinarachnius* J. E. Gray, 1825

Echinarachnius J. E. Gray, 1825, Annal. Philos., vol. 26, (n.s. vol. 10), p. 428.

Genologotype: *Echinarachnius parma* (Lamarck) Gray, 1825, op. cit., p. 428. (Atlantic Ocean; Brit. Mus.?).=*Scutella parma* J. Lamarck, 1816, Hist. Nat. Anim. sans Vert., 3, p. 11. ('l'Océan des Indes'; Paris Mus.).

Type by subsequent designation by L. Agassiz, 1841, Monogr. Ech., Monogr. Scut., p. 88.

Subgenus *Scaphechinus* Al. Agassiz, 1863.

Scaphechinus Al. Agassiz, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 359.

Haplotype: *Scaphechinus mirabilis* Al. Agassiz, 1863, op. cit., p. 359. (Hakodate Bay; W. Stimpson Coll.; Mus. Comp. Zool.).

Type by monotypy.

Echinarachnius (*Scaphechinus*) *mirabilis* (Al. Agassiz, 1863) Al. Agassiz, 1872

Echinarachnius mirabilis (Al. Agassiz) Al. Agassiz, 1872, Mem. Mus. Comp. Zool., Harvard College, vol. 3, pp. 107, 526, pl. 16, f. 9, 10. (Hakodate Bay; W. Stimpson Coll.; Mus. Comp. Zool.).—H. Ikeda, 1935, Bull. Fac. Sci. Kyûsyû Imp. Univ., vol. 6, p. 202, pl. 4, f. 5–8. (Tuyasaki; Zool. Inst., Kyûsyû Imp. Univ.).

Materials: About two hundred specimens, 7 to 52 mm. in longitudinal diameter.

Occurrence: Station 3: off Tyôsi, 13 metres. (Reg. No. 58325).
Station 4: off Tyôsi, 12 metres. (Reg. No. 58326).
Station 9: off Inubô-zaki, 8 metres. (Reg. No. 58327).
Station 23: off Iioka, 12 metres. (Reg. No. 58328).
Station 24: off Iioka, 24 metres. (Reg. No. 58329).

Distribution: Japan; Amakusa (Ikeda), Hakata Bay (Ikeda), Tuyasaki (Ikeda), Tomo (Ikeda), Inland Sea (H. L. Clark), Misaki (H. L. Clark), Tokyo Bay (von Martens), off Kazusa, Sendai Bay, Mutu Bay (Th. Mortensen), Hakodate Bay (Al. Agassiz), Otaru (Ikeda).

Range in depth: 0 to 60 metres.

Genus *Echinolampas* J. E. Gray, 1825

Echinolampas J. E. Gray, 1825, Annal. Philos., vol. 26, (n.s. vol. 10), p. 429.

Genohaplotype: *Echinus oviformis* H. Gmelin, 1797, Syst. Nat., ed. 13, p. 3187. (South Sea; Coll. Péron and Lesueur; Paris Mus.). =*Echinanthus ovatus* N. G. Leske, 1778, Addit. ad Klein nat. Disposit. Ech., p. 121. (Indian Ocean).

Type by monotypy.

Echinolampas sternopetala Al. Agassiz et H. L. Clark, 1907

Echinolampas sternopetala Al. Agassiz and H. L. Clark, 1907, Bull. Mus. Comp. Zool., Harvard College, vol. 51, p. 130. (Albatross Stations 3749, off Suno-saki, in 126–240 metres; 4934, off Kagosima Bay, in 167–232 metres; Mus. Comp. Zool.).—H. L. Clark, 1917, Mem. Mus. Comp. Zool., Harvard College, vol. 46, p. 115, pl. 147, f. 1, 2, pl. 153, f. 5–7, pl. 144, f. 20–24. (Ibid.: lectotype, Station 4934, off Kagosima Bay).

Materials: One bare test, 67 mm. in longitudinal diameter, and a fragment.

Occurrence: Station 45: off Ôhara, 130.5 metres. (Reg. No. 58330).

Distribution: Near the Kei Islands (Challenger): Japan; Kagosima Bay (H. L. Clark), Misaki (H. L. Clark), off Suno-saki (H. L. Clark), off Kazusa, Wakasa Bay (H. Niino).

Range in depth: 100–240 metres.

Genus *Pseudomaretia* R. Koehler, 1914

Pseudomaretia R. Koehler, 1914, Echinod. Indian Mus., 8, Ech., (1), p. 107.

Genorthotype: *Maretia alta* Al. Agassiz, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 360. (Kagosima Bay; W. Stimpson Coll.; Mus. Comp. Zool.; U. S. National Mus.).

Type by original designation.

Pseudomaretia alta (Al. Agassiz, 1863) R. Koehler, 1914

Pseudomaretia alta (Al. Agassiz) R. Koehler, 1914, Echinod. Indian Mus., 8, Ech., (1), p. 111, pl. 11, f. 14–17, 20, pl. 20, f. 1–7. (Investigator Station 158, 14°04′57″N., 20°50′E., in 52 metres; Pedro Shoal; Andaman Island; Sept-Pagodes; Calcutta Mus.).

Maretia clta Al. Agassiz, 1863, Proc. Acad. Nat. Sci. Philadelphia, p. 360. (loc. cit.).

Materials: Nine specimens, 26 to 46 mm. in longitudinal diameter.

Occurrence: Station 25: off Iioka, 39 metres. (Reg. No. 58332).

Distribution: Mauritius: Ceylon: East Indies: Japan; Formosa, Kagosima Bay (Al. Agassiz), off Kadusa, Kohama Bay (Ikeda).

Range in depth: 1.5–64 metres.

Genus *Echinocardium* J. E. Gray, 1825

Echinocardium J. E. Gray, 1825, Annal. Philos., vol. 26, (n.s. vol. 10), p. 430.

Genologotype: *Spatangus pusillus* N. G. Leske, 1778, Addit. ad Klein nat. Disposit. Ech., p. 230, pl. 24, f. c–e. (non O. F. Müller, 1776). (North Sea) = *Echinus cordatus* Th. Pennant, 1777, Brit. Zool., vol. 4, p. 69, pl. 34, f. 75. (North Sea).

The fixation of this genus was fully discussed by Th. Mortensen, 1932, Ann. Mag. Nat. Hist., ser. 10, vol. 10, p. 358.

Echinocardium cordatum (Th. Pennant, 1777) J. E. Gray, 1851

Echinocardium cordatum (Pennant) J. E. Gray, 1851, Ann. Mag. Nat. Hist., ser. 2, vol. 7, p. 131. (North Sea; Brit. Mus.?).—F. J. Bell, 1892, Cat. Brit. Echinod. Brit. Mus., p. 169, pl. 16, f. 1–4. (British Coast; Mediterranean; Brit. Mus.).—Th. Mortensen, 1907, Dan. "Ingolf" Exp., vol. 4, Ech., 2, p. 145, pl. 16, f. 21, pl. 17, f. 15, 21–23,

37–38, 43, 48, 49. (Examined numerous forms.).

Materials: Seventy-five specimens, from 21 to 46 mm. in longitudinal diameter.

Occurrence: Station 15: off Inubô-zaki, 40 metres. (Reg. No. 58333).

Station 25: off Iioka, 39 metres. (Reg. No. 58334).

Station 26: off Kuriyama-gawa, 21 metres. (Reg. No. 58335).

Station 27: off Kuriyama-gawa, 17 metres. (Reg. No. 58336).

Station 29: off Kuriyama-gawa, 10 metres. (Reg. No. 58337).

Station 37: off Hamazyûku, 21 metres. (Reg. No. 58338).

Station 42: off Itinomiya, 15.4 metres. (Reg. No. 58339).

Distribution: North Sea; England: Ireland: Bay of Biscay: Mediterranean: Nice: Marseilles: Naples: Sicily: Cape of Good Hope: False Bay: Port Jackson: Tasmania: Port Philip: South Australia: West Australia: New Zealand: Japan; Coast of Korea (H. L. Clark), Inland Sea (Challenger), off Kobe (Challenger), off Yokkaiti (H. L. Clark), Tokyo Bay (H. L. Clark), near Kinkazan Light House (H. L. Clark); Mutu Bay (Th. Mortensen).

Range in depth: 0–90 metres.

Studies on the Vertical Distribution of the Plankton Crustacea

I. A Comparison of the Vertical Distribution of the Plankton Crustacea in Six Lakes of Middle Japan in Relation to the Underwater Illumination and the Water Temperature

By

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With 7 Text-figures and 18 Tables

I. Introductory

Studying the diurnal migration of plankton copepods with the simultaneous measurements of submarine irradiation in the Gulf of Maine, Clarke (1933, 1934) points to the fact that the light is a predominating factor controlling the vertical distribution of the zooplankton. This similarity is also true of Russel's observations (1934) on this line in the English Channel near Plymouth. With a view to elucidating this respect on the vertical distribution of the plankton crustaceans in the lakes of Kizaki, Aoki, Motosu, Nisi, Kawaguti and Biwa, observations were made in August and September of 1935.

Before proceeding further, it might be mentioned that this investigation was prosecuted by a grant of the research fund from the Japan Society for the Promotion of Scientific Research. During the course of this work, I am very much indebted to Messrs. M. Kawajiri and K. Hata, and other members of the staff of the Kizaki Station of the Imperial Fisheries Experimental Institute and to Professor K. Sugawara of the Tokyo High School for furnishing me with the hydrographical data as well as for a great deal of help in the operation at the lakes. My best thanks are also due to Professor T. Kawamura and Dr. M. Ueno of the Kyoto Imperial University for facilities given at the laboratory of the Otsu Hydrobiological Station and to Professor T. Kaburaki of the Tokyo Imperial University for criticism.

II. Methods

1) For making catches of the plankton, was employed the plankton-catcher which was made on the line of STRÖM's type (cf. STRÖM, 1931). It consists of a brass cylinder which can be shut by lids at both ends by means of a release mechanism. The cylinder is 15 litres in volume, 60 cm. in height and 18 cm. in diameter. Four windows covered by a net run in two series from the top to the bottom of the cylinder. A small bucket whose side is made from a net, is attached to the center of the lower lid. The net consists of brass wire, 0.05 mm. in diameter, and a mesh is 0.12 mm. square in area (60 meshes/cm.), in order to render the apparatus reliable with regard to the plankton crustaceans. The cylinder has three legs which make operation for opening the lids or gathering the plankton much more convenient. In the case of Lake Biwa, the same type of the plankton-catcher, 10 litres in volume, was used. The general construction is shown in Fig. 1.

When the plankton catch was made, the apparatus was lowered into the water after the lids had been opened on the boat, so that the water flows freely through the cylinder. When arrived at a desired depth, a messenger was allowed to slide down the rope, and the lids were automatically shut. Then the apparatus was raised and taken on the boat. The water in the cylinder was filtered through the windows of the cylinder and the small bucket of the lower lid, so that all the plankton in 15 litres of the water at a desired depth were gathered in the bucket. By opening the stop cock of the bucket, they were collected in a glass tube and a small amount of formalin was added. The plankton catches were made at intervals of 2 or 3 m. from the surface to a depth of 20 or 25 m. It needed about 30 minutes for making a series of plankton catches.

After the plankton materials were brought back to the laboratory all the plankton of each catch were examined and counted on a ruled slide glass under the microscope. Thus the number of individuals of each species in a litre of water at different levels was indicated in tabular form, from which are computed the total number of individuals within a column of the water, 10 cm. square in cross section, from the surface to a depth of 20 or 25 m., and the depths of the upper and the lower limit, of the lower and the upper quartile, and of the median in the vertical distribution of the plankton. For calculating these

values, it is necessary to make the assumption that the number of individuals in each litre increases or decreases from a stratum to another by a rectilinear proportion.

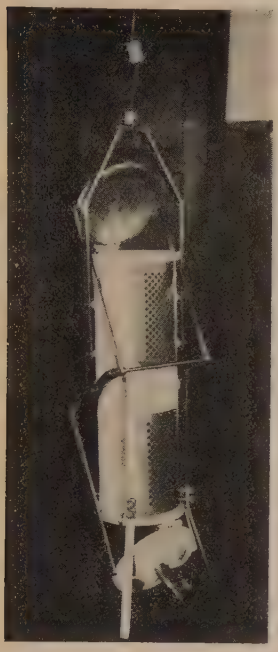

Fig. 1. The plankton catcher.

Fig. 2. The apparatus for measuring the underwater illumination.

a, photometer;
b, photo-cell;
c, cable;
d, shunt box;
e, galvanometer.

2) For measuring the underwater illumination, was used Mazda selenium rectifier photo-electric cell made by the Tokyo Electric Co., keeping it in the photometer which consists of a cylindrical iron box. In front of the glass window of the photometer was set a disc of opal flashed glass without using any colour filter. The general construction is as in Fig. 2. The photoelectric current is related to the illumination by a rectilinear proportion, and is 4–5 mA. under the full sunlight at noon in summer.

Lowering the photometer into the water, the electric current was measured at an interval of 1 m. from the surface to a depth of 20 m. by an unipivot pointer galvanometer on the boat. The resistance of the galvanometer is 10 ohms, each scale division being 5 microamps. The underwater illumination is given in the tables in percent of the light intensity in air at the time the total energy of the solar radiation is 80 mW.

The total energy of the solar radiation in air was measured by the thermopiles of the Oyama solarimeter made by the Yokokawa Electric Works (cf. OYAMA, 1928), which is composed of constantan-manganin couples mounted in a hemispherical vacuum glass bulb. The current from the thermopiles was measured by an unipivot pointer galvanometer. According to data supplied by the Works, 150 mW/cm^2/min in energy of radiation gives a current of 20.49 mV.

3) Records of the water temperature were taken by Mr. K. HATA at Lake Kizaki and Lake Aoki and by Dr. M. UENO at Lake Biwa by using the Kitahara water-sampler and a rod thermometer, while in the cases of the lakes, Motosu, Nisi and Kawaguti, a reversing thermometer was employed by Professor K. SUGAWARA.

4) The hydrogen ion concentration of the water was determined by the method described by CLARKE. The indicator employed was a solution of Brom Thymol Blue and Cresol Red. It was found to have

Table I. The light intensity in the water

Lake	Biwa	Kizaki	Kawaguti	Aoki	Nisi	Motosu
Date	Sept. 29	Aug. 4	Aug. 21	Aug. 5	Aug. 20	Aug. 19
Time	10.30 A.M.	11.30 A.M.	10.30 A.M.	11.15 A.M.	2.40 P.M.	2.30 P.M.
Transp.	4.5 m.	5.0 m.	5.0 m.	9.5 m.	10.5 m.	12.5 m.
L. i. in air	47.3 mW. 59%	45.5 mW. 57%	80.7 mW. 101%	46.5 mW. 58%	69.5 mW. 87%	78.0 mW. 98 %
0.01 m.	46%	30%	52%	23%	46%	50%
0.5	31	24	44	—	—	—
1	27	19	34	20	36	40
2	16	14	27	18	30	34
3	12	9.5	15	11	25	31
4	10	6.3	10	9.0	19	22
5	7.0	4.2	7.5	7.5	15	21
6	5.5	3.3	4.8	6.5	13	18
7	3.9	1.6	2.9	6.0	12	15
8	2.8	1.2	1.8	4.7	10	13
9	2.0	0.93	1.1	4.2	8.0	12
10	1.5	0.66	0.85	3.6	6.5	11
11	1.1	0.54	0.60	3.0	5.0	9.0
12	0.80	0.45		2.6	4.0	7.5
13	0.50	0.36		2.0	3.2	6.5
14	0.45	0.33		1.6	3.2	6.0
15	0.30	0.26		1.3	2.4	5.5
16	0.20	0.23		1.1	2.4	4.8
17	0.15	0.20		0.9	1.6	4.0
18	0.10	0.17		0.8	1.6	3.4
19	0.05	0.15		0.7	1.6	3.4
20	0·05	0.13		0.6	1.2	3.2

Table II. The temperature of the water

Lake	Biwa	Kizaki	Kawaguti	Aoki	Nisi	Motosu
0 m.	22.1	26.0	23.1	26.7	23.0	22.8
2	22.0	25.7	23.1	—	—	22.8
5	21.9	21.6	22.8	25.4	21.7	21.6
8	—	15.2	17.6	17.6	—	—
10	21.8	11.5	16.4	12.6	14.7	21.5
12	—	10.6	15.0	—	—	—
15	21.4	—		—	—	14.3
20	11.6	7.5		7.8	12.0	9.8

a range from pH 6.4 to 7.9, but no connection with the vertical distribution of the plankton was detected.

III. Vertical Distribution of Individual Species

In order to ascertain the relation between the underwater illumination and the vertical distribution of the individual species of the plankton, seven series of the plankton catches were made with the simultaneous measurements of the underwater illumination and of the water temperature, in Lake Kizaki at 11.30 A.M. and 2.30 P.M. on August 4, in Lake Aoki at 11.15 A.M. on August 5, in Lake Motosu at 2.30 P.M. on August 19, in Lake Nisi at 2.30 P.M. on August 20, in Lake Kawaguti at 10.30 A.M. on August 21, and in Lake Biwa at 10.30 A.M. on September 29. Readings of the underwater illumination and the water temperature are given in Tables I, II and Fig. 3.

A consistent but rough correlation was demonstrated between the

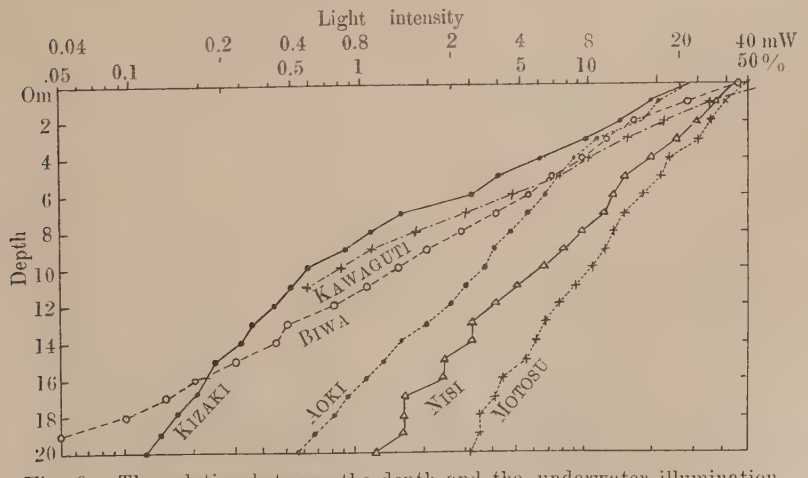

Fig. 3. The relation between the depth and the underwater illumination.

underwater illumination and the vertical distribution in the cases of *Bosminopsis deitersi, Polyphemus pediculus, Holopedium gibberum, Diaphanosoma brachyurum* and *Leptodora Kindtii.* So far as observations went, the effect of the water temperature could hardly be discerned in these species.

1. *Bosminopsis deitersi* (Table III, Fig. 4)

Amongst the plankton crustaceans examined, this species was distributed at the uppermost level. The light intensity at the depth of the median of the population was found to range from 11% in Lake Kizaki(I) to 4.5% in Lake Aoki, the mean being 7.4%.

Table III. The vertical distribution of *Bosminopsis deitersi*

Kizaki(I), Lake Kizaki at 11.30 A.M.; Kizaki(II), Lake Kizaki at 2.30 P.M.; D, Depth; L, Light intensity; T, Temperature; u.l., the upper limit; l.l., the lower limit; q_1, the upper quartile; q_2, the median; q_3, the lower quartile.

Lake	Kizaki (I)	Kizaki (II)	Aoki	Nisi	Motosu
0 m.	0	0	0	0	0
2	3.93	10.3	0.07	0	0
5	0.26	2.07	2.97	0.07	0
8	0.07	0.20	16.5	0.33	0
10	0	0.07	11.6	0.33	1.98
12	0	0	2.18	0.13	5.28
15	0	0	0.13	0	0.07
20	0	0	0	0	0
Total	108	362	795	20.5	175
D. q_1 (m)	1.4	1.6	6.6	7.0	10.6
D. q_2 (m)	2.7	3.0	8.4	8.8	11.9
D. q_3 (m)	4.0	4.2	9.7	10.6	13.4
L. u. l. (%)	—	—	18	15	11
L. q_1 (%)	17	9.3	6.3	12	9.4
L. q_2 (%)	11	5.5	4.5	8.4	7.7
L. q_3 (%)	6.3	3.4	3.8	5.6	6.3
L. l. l. (%)	1.2	0.38	1.3	4.0	5.5
T. q_1 (°C)	25.8	25.8	21.2	18.9	20.6
T. q_2 (°C)	24.7	24.3	16.6	16.3	18.8
T. q_3 (°C)	23.0	22.7	12.1	14.5	16.9

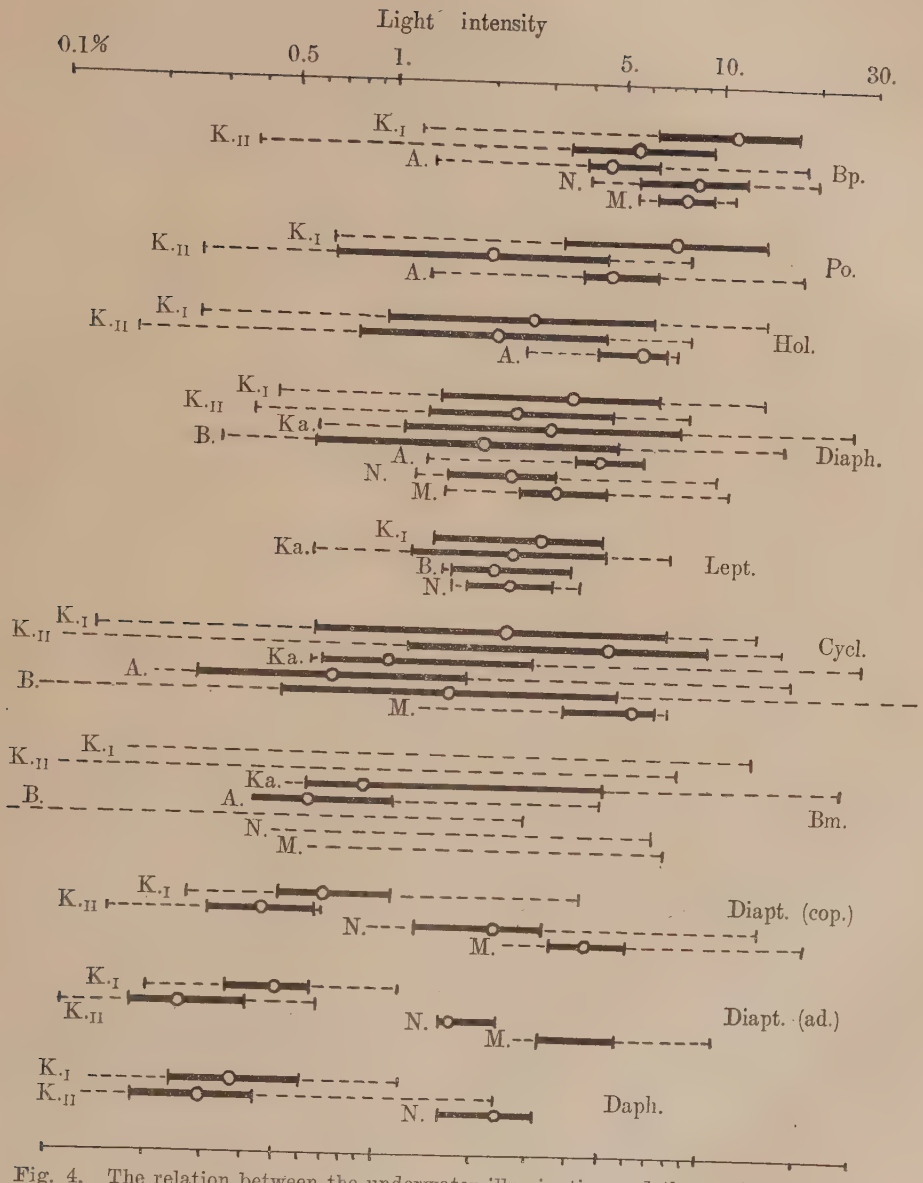

Fig. 4. The relation between the underwater illumination and the vertical distribution of the plankton.

The circle indicates the light intensity at which the median of the population is found. The thick line, the range of the light intensity between the upper and the lower quartiles. The broken line, the range of the light intensity between the upper and the lower limit. Ka., Lake Kawaguti; A, Lake Aoki; B, Lake Biwa; N., Lake Nisi; M., Lake Motosu. Abbreviations as in Tables III and XIV.

2. *Polyphemus pediculus* (Table IV and Fig. 4)

This species was found to occur in two of the lakes examined and to change its vertical distribution in wide range according to different hours of the day. The light intensity at the depth of the median of the population was found to be 7.3% at 11.30 A.M. and 2.0% at 2.30 P.M. in Lake Kizaki and 4.6% in Lake Aoki, the mean being 4.6%.

Table IV. The vertical distribution of *Polyphemus pediculus*

Lake	Kizaki (I)	Kizaki (II)	Aoki
0 m.	0	0	0
2	1.32	0.80	0.07
5	0.13	1.20	0.53
8	0.26	0.80	4.62
10	0.20	0.47	1.98
12	0	0.20	0.20
15	0	0	0.07
20	0	0	0
Total	47.5	90.4	171.
D. q_1 (m)	1.9	3.5	6.5
D. q_2 (m)	3.7	5.7	8.3
D. q_3 (m)	6.0	8.0	9.6
L. u. l. (%)	—	8.2	18.
L. q_1 (%)	14.	4.5	6.4
L. q_2 (%)	7.3	2.0	4.6
L. q_3 (%)	3.3	0.67	3.8
L. l. l. (%)	0.66	0.26	1.3
T. q_1 (°C)	25.7	23.6	21.4
T. q_2 (°C)	23.3	20.1	16.8
T. q_3 (°C)	19.5	15.2	13.6

3. *Holopedium gibberum* (Table V and Fig. 4)

The light intensity at the depth of the median of the population was found to be 2.7% at 11.30 A.M. and 2.1% at 2.30 P.M. in Lake Kizaki and 5.9% in Lake Aoki, the mean being 3.6%.

Table V. The vertical distribution of *Holopedium gibberum*

Lake	Kizaki (I)	Kizaki (II)	Aoki
0 m.	0	0	0
2	3.89	2.33	0
5	3.96	4.53	1.45
8	7.26	3.33	2.97
10	2.44	0.87	0.66
12	0.99	0.73	0.20
15	0.07	0.07	0
20	0	0.20	0
Total	468.	301.	136.
D. q_1 (m)	4.0	3.5	5.6
D. q_2 (m)	6.3	5.6	7.1
D. q_3 (m)	8.6	7.5	8.8
L. u. l. (%)	14.	8.2	7.5
L. q_1 (%)	6.3	4.5	6.9
L. q_2 (%)	2.7	2.1	5.9
L. q_3 (%)	0.96	0.79	4.3
L. l. l. (%)	0.26	0.07	2.6
T. q_1 (°C)	23.0	23.6	23.8
T. q_2 (°C)	18.9	20.3	19.9
T. q_3 (°C)	14.1	16.3	15.6

4. *Diaphanosoma brachyurum* (Table VI and Fig. 4)

Amongst the plankton crustaceans examined, this species exhibited the most consistent results. The light intensity, to which the median of the population was subjected, was 1.9% in Lake Biwa, 2.4% in Lake Nisi, 3.6% at 11.30 A.M. and 2.4% at 2.30 P.M. in Lake Kizaki, 3.1% in Lake Kawaguti, 3.2% in Lake Motosu, and 4.4% in Lake Aoki, the mean being 3.0%.

Table VI. The vertical distribution of *Diaphanosoma brachyurum*

Lake	Kizaki(I)	Kizaki(II)	Kawaguti	Biwa	Aoki	Nisi	Motosu
0 m.	0	0	0	0	0	0	0
2	2.41	2.33	1.12	0.4	0	0	0
5	16.2	30.0	2.64	2.6	0	0	0
8	10.6	2.33	4.09	2.3	38.0	0.66	0
10	1.52	0.67	1.42	2.3	30.4	4.29	0.07
12	0.07	0	2.41	1.8	1.19	23.8	0.99
15	0	0	—	1.0	0.13	26.4	4.62
18	—	—	—	—	—	18.5	—
20	0	0	—	0	0	11.2	11.9
25	—	—	—	—	—	9.90	7.26
Total	844.	1030.	262.	272.	1593.	2610.	987.

Table VI—(*Continued*)

D. q_1 (m)	3.9	3.4	4.9	6.4	7.0	13.2	16.8
D. q_2 (m)	5.7	5.0	6.9	9.2	8.6	15.9	19.8
D. q_3 (m)	7.5	6.6	9.0	12.7	9.8	19.2	22.4
L. u. l. (%)	14.	8.2	27.	16.	—	10.	11.
L. q_1 (%)	6.6	4.7	7.8	4.9	6.0	3.2	4.6
L. q_2 (%)	3.6	2.4	3.1	1.9	4.4	2.4	3.2
L. q_3 (%)	1.4	1.3	1.1	0.59	3.7	1.5	2.5
L. l. l. (%)	0.45	0.38	(0.6)	0.30	1.3	(1.2)	—
T. q_1 (°C)	23.1	23.7	21.9	22.8	20.1	14.2	12.7
T. q_2 (°C)	20.1	21.6	21.8	19.2	16.1	13.1	9.9
T. q_3 (°C)	16.3	18.2	21.5	17.0	13.1	12.2	8.8

5. *Leptodora Kindtii* (Table VII and Fig. 4)

The light intensity at the depth of the median of the population was found to be 2.2% in Lake Biwa, 2.4% in Lake Nisi, 2.5% in Lake Kawaguti, and 3.0% in Lake Kizaki, the mean being 2.5%.

Table VII. The vertical distribution of *Leptodora Kindtii*

Lake	Kizaki (I)	Kawaguti	Biwa	Nisi
0 m.	0	0	0	0
2	0	0	0	0
5	0.07	0.13	0	0
8	0.07	0.66	0.1	0
10	0	0.07	0.1	0
12	0	0.13	0	0.07
15	0	—	0	0.13
18	—	—	—	0.07
20	0	—	0	0
25	0	—	0	0
Total	3.7	23.3	4.5	7.4
D. q_1 (m)	4.8	6.0	7.2	13.1
D. q_2 (m)	6.2	7.4	8.7	15.0
D. q_3 (m)	7.6	8.9	9.8	16.8
L. u. i. (%)	—	7.5	—	4.0
L. q_1 (%)	4.6	4.8	3.7	3.2
L. q_2 (%)	3.0	2.5	2.2	2.4
L. q_3 (%)	1.4	1.2	1.6	1.8
L. l. l. (%)	—	(0.6)	1.5	1.6
T. q_1 (°C)	21.9	20.5	21.8	13.9
T. q_2 (°C)	19.1	18.5	21.8	13.3
T. q_3 (°C)	16.0	16.2	21.8	12.9

6. *Cyclops strenuus* (Table VIII and Fig. 4)

The vertical distribution of this species was of much wider range

than that of the five species just mentioned. The light intensity at the depth of the median of the population ranged from 0.7% in Lake Aoki to 5.8% in Lake Motosu, the mean being 2.1%. In Lake Nisi only a few individuals were obtained. In Lake Kizaki and Lake Aoki a considerable number of *Cyclops vicinus* were obtained together with *Cyclops strenuus*. It was impossible to distinguish these two species in the copepodid stage, but it can be said in general that *Cyclops vicinus* was distributed in an upper stratum than *Cyclops strenuus*.

Table VIII. The vertical distribution of *Cyclops strenuus*

Lake	Kizaki (I)	Kizaki (II)	Kawaguti	Aoki	Biwa	Motosu
0 m.	0.13	0.07	0.07	0	0.5	0
2	2.20	2.53	0.53	0.07	0.2	0
5	3.66	5.67	0.40	0	2.4	0
8	1.14	1.53	0.27	2.33	2.6	0
10	2.20	1.47	3.33	1.13	1.1	0
12	1.33	1.60	1.00	4.33	3.2	1.67
15	0.40	1.00	—	3.67	0.8	1.00
20	0.40	0.53	—	3.33	1.0	0.13
25	—	—	—	—	—	0.33
30	—	—	—	1.00	—	—
50	—	—	—	0.47	—	—
Total	298.	395.	109.	750.	306.	96.5
D. q_1 (m)	3.7	3.8	7.1	13.5	6.2	12.6
D. q_2 (m)	6.5	6.4	9.3	18.7	9.8	14.4
D. q_3 (m)	10.3	10.7	10.7	25.2	13.2	17.7
L. u. l. (%)	—	17.	30.	18.	46.	7.5
L. q_1 (%)	7.3	4.0	2.8	1.8	5.2	6.9
L. q_2 (%)	2.4	1.5	1.0	0.7	1.6	5.8
L. q_3 (%)	0.92	0.33	0.65	—	0.49	3.6
L. l. l. (%)	0.13	0.07	0.60	—	0.05	—
T. q_1 (°C)	23.3	23.1	19.2	11.9	21.9	19.7
T. q_2 (°C)	18.4	12.2	16.8	8.3	21.8	15.3
T. q_3 (°C)	11.4	11.0	15.9	—	21.5	11.9

7. *Bosmina longirostris* (Table IX and Fig. 4)

This species was taken in all the lakes examined but its vertical distribution exhibited a lack of consistency. In Lake Biwa, Lake Nisi,

and Lake Motosu the number of individuals was very small but it was possible to say that the animals shuned the strong light and none was taken in the surface layer where the light intensity was higher than 2.8% in Lake Biwa, 6.5% in Lake Nisi, and 7.5% in Lake Motosu. In Lake Kizaki the animals were distributed uniformly from a depth of 2 m. to the bottom. In Lake Aoki the upper limit of the distribution was found at a depth of 8 m. (l.i.=4.7%) and the median at

Table IX. The vertical distribution of *Bosmina longirostris* and *Bosmina coregoni Amemiyai*

	Bosimina longirostris							*B. cor.*
Lake	Kizaki (I)	Kizaki (II)	Kawa-guti	Aoki	Biwa	Nisi	Motosu	Kawa-guti
0 m.	0	0	0	0	0	0	0	0.53
2	0.79	0.53	0.59	0	0	0	0	0.53
5	0.99	0.73	0.26	0	0	0	0	0.47
8	0.40	0.53	0.26	0.53	0.2	0	0	0.33
10	0.46	0.20	1.79	1.65	0.1	0.13	0	0.33
12	0.07	0.27	2.51	4.62	0.6	0	0.07	0.35
15	0.13	0.27	—	7.59	0.2	0.20	0.07	—
18	—	—	—	—	—	0.13	—	—
20	0.86	1.00	—	8.25	0.1	0.13	0.20	—
25	—	—	—	—	—	0.13	0.13	—
30	—	—	—	1.65	—	—	—	—
50	—	—	—	0.26	—	—	—	—
Total	96.7	94.9	90.0	1347.	25.5	19.9	17.9	267.
D. q_1 (m)	—	—	6.4	15.9	—	—	—	2.7
D. q_2 (m)	—	—	9.8	20.3	—	—	—	4.7
D. q_3 (m)	—	—	11.0	27.1	—	—	—	6.9
L. u. l. (%)	14.	8.2	27.	4.7	2.8	6.5	7.5	52.
L. q_1 (%)	—	—	4.1	1.1	—	—	—	19.
L. q_2 (%)	—	—	0.90	0.6	—	—	—	8.3
L. q_3 (%)	—	—	0.60	—	—	—	—	3.1
L. l. l. (%)	0.13	0.07	—	—	0.05	—	—	—
T. q_1 (°C)	—	—	23.0	11.8	—	—	—	23.1
T. q_2 (°C)	—	—	16.5	7.8	—	—	—	11.8
T. q_3 (°C)	—	—	15.7	—	—	—	—	9.6

23 m. (l.i.=0.6%). In Lake Kawaguti the animals crowded near the bottom (l.i.=0.6%).

8. *Bosmina coregoni Amemiyai* (Table IX)

This species, differing from *Bosmina longirostris*, was found only in Lake Kawaguti, to range from the surface to the bottom, the median of the population being found at a depth of 4.7 m. (l.i.=8.3%). According to Ueno (1936), *Bosmina coregoni* was distributed in the surface layer in Lake Akan.

9. *Acanthodiaptomus pacificus* var. *yamanacensis* (Tables X–XI, Figs. 4–5)

The vertical distribution of this species was of entirely different type. During the daytime no consistent correlation between the underwater illumination and the vertical distribution was observed. The animals were distributed in or below the thermocline during the daytime when the temperature of the surface water was higher than 22°C, and came up to the surface layer after sunset. This similarity is also true of *Epischura lacustris* and *Mysis relicta* (Juday, 1902, 1927).

The upper limit of the vertical distribution of the copepodid in Lake Kizaki at 11.30 A.M. was found at a depth of 5 m. (temp.=21.6°C; l.i.=4.2%) and the median at a depth of 9.9 m. (temp.=11.7°C;

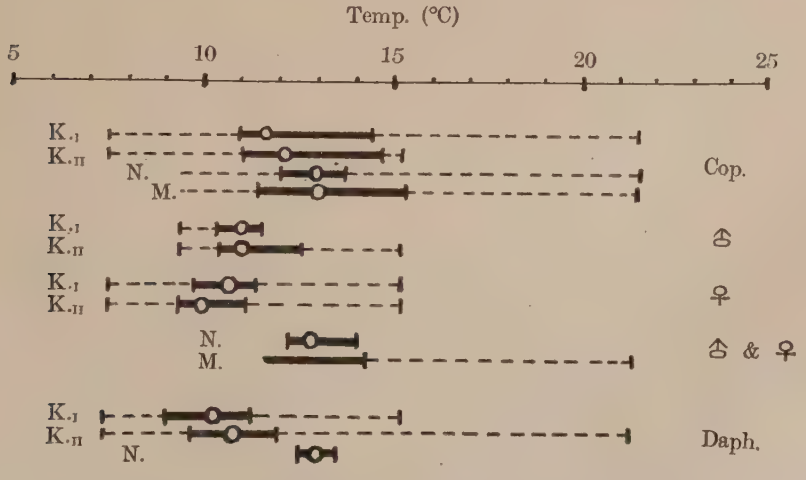

Fig. 5. The relation between the water temperature and the vertical distribution of *Acanthodiaptomus* and *Daphnia*. Abbreviations as in Tables III, XIV and Fig. 4.

Table X. The vertical distribution of *Acanthodiaptomus pacificus* var. *yamanacensis* in Lake Kizaki at (I) 11.30 A.M. and (II) 2.30 P.M.

	Copepodid		Male		Female	
Time	(I)	(II)	(I)	(II)	(I)	(II)
0 m.	0	0	0	0	0	0
2	0	0	0	0	0	0
5	0.07	0	0	0	0	0
8	1.98	2.67	0	0.53	0.13	0.40
10	4.29	4.13	1.33	1.33	1.33	0.67
12	1.20	1.47	0.80	1.60	1.20	1.47
15	0.33	0.13	0.13	0.07	0.47	0.80
20	0	0	0	0	0.47	0.20
Total	172.	191.	51.8	82.5	80.4	91.1
D. q_1 (m)	8.4	8.2	10.0	9.4	10.3	10.8
D. q_2 (m)	9.9	9.6	11.1	11.0	11.9	13.1
D. q_3 (m)	11.5	11.2	12.9	12.7	14.2	15.8
L. u. l. (%)	4.2	2.4	—	0.67	1.2	0.67
L. q_1 (%)	1.1	0.64	0.66	0.47	0.62	0.32
L. q_2 (%)	0.69	0.44	0.53	0.31	0.46	0.20
L. q_3 (%)	0.50	0.30	0.37	0.22	0.32	0.14
L. l. l. (%)	0.26	0.15	0.26	0.15	0.13	0.07
T. u. l. (°C)	21.6	15.2	11.5	15.2	15.2	15.2
T. q_1 (°C)	14.5	14.8	11.5	12.6	11.3	11.1
T. q_2 (°C)	11.7	12.2	11.0	11.0	10.7	10.0
T. q_3 (°C)	10.9	11.0	10.3	10.4	9.8	9.3

l.i.=0.69%). The upper limit in the same lake at 2.30 P.M. at 8 m. (temp.=15.2°C; l.i.=2.4%) and the median at 9.6 m. (temp.=12.2°C; l.i.=0.44%). In Lake Nisi the upper limit at 5 m. (temp.=21.7°C; l.i.=15%) and the median at 16.1 m. (temp.=13.0°C; l.i.=2.3%). In Lake Motosu the upper limit at 5 m. (temp.=21.6°C; l.i.=21%) and the median at 16.4 m. (temp.=13.0°C; l.i.=4.4%).

In Lake Kizaki the adult male frequented deeper strata than the copepodid did and the adult female deeper than the adult male. The adult male was taken below 10 m. (temp.=11.5°C; l.i.=0.66%) at 11.30 A.M. and below 8 m. (temp.=15.2°C; l.i.=0.67%) at 2.30 P.M.

Table XI. The vertical distribution of *Acanthodiaptomus pacificus* var. *yamanacensis* in Lake Nisi and Lake Motosu

	Copepodid		Adult	
Lake	Nisi	Motosu	Nisi	Motosu
0 m.	0	0	0	0
2	0	0	0	0
5	0.20	0.07	0	0
8	0.07	0.13	0	0
10	0.66	0.66	0	0.07
12	2.31	2.00	0	0
15	3.33	4.62	0.33	0.20
18	2.00	—	0.99	—
20	1.32	2.97	0	0.26
25	1.65	2.00	0	0.20
Total	316.	452.	34.8	27.4
D. q_1 (m)	(13.2)	(14.3)	15.6	—
D. q_2 (m)	(16.1)	(16.4)	16.9	—
D. q_3 (m)	(19.7)	(18.1)	18.3	—
L. u. l. (%)	15.	21.	—	11.
L. q_1 (%)	3.2	5.8	2.4	—
L. q_2 (%)	2.3	4.4	1.7	—
L. q_3 (%)	1.3	3.4	1.6	—
T. u. l. (°C)	21.7	21.6	—	21.5
T. q_1 (°C)	13.8	15.3	14.1	—
T. q_2 (°C)	13.0	13.0	12.9	—
T. q_3 (°C)	12.1	11.5	12.3	—

The median of the population was found at 11.1 m. (temp.=11.0°C; l.i.=0.53%) at 11.30 A.M. and at 11.0 m. (temp.=11.0°C; l.i.=0.31%) 2.30 P.M. The adult female was distributed below a depth of 8 m. (temp.=15.2°C; l.i.=1.2% at 11.30 A.M., and 0.67% at 2.30 P.M.), the median of the population being found at 11.9 m. (temp.=10.7°C; l.i.=0.46%) at 11.30 A.M. and 13.1 m. (temp.=10.0°C; l.i.=0.20%) at 2.30 P.M.

In Lake Nisi the adults were taken between the depths of 15 and 20 m. (temp.=13.4−12.0°C; l.i.=2.4−1.2%), the median being found at a depth of 16.9 m. (temp.=12.9°C; l.i.=1.7%). In Lake Motosu

the upper limit of the vertical distribution of the adults was found at a depth of 10 m. (temp.=21.5°C; l.i.=11%) and the majority were taken below a depth of 15 m. (temp.=14.3°C; l.i.=5.5%).

10. *Daphnia longispina* (Table XII and Figs. 4, 5)

This species presented another type of the vertical distribution. In the daytime it was distributed almost at the same level where *Acanthodiaptomus pacificus* var. *yamanacensis* was obtained, though the upward migration at night was retarded above the thermocline, as is the case of *Daphnia hyalina, D. longiremis, D. pulicaria,* and *Limnocalanus macrurus* observed by JUDAY (1903).

In Lake Kizaki the upper limit of the vertical distribution was found at a depth of 5 m. (temp.=21.6°C; l.i.=4.2% at 11.30 A.M. and 2.4% at 2.30 P.M.) and the majority below a depth of 8 m. (temp.=

Table XII. The vertical distribution of *Daphnia longispina*

Lake	Kizaki (I)	Kizaki (II)	Nisi
0 m.	0	0	0
2	0	0	0
5	0	0.13	0
8	0.99	7.00	0
10	10.9	14.0	0
12	6.93	9.33	0
15	4.95	3.07	0.99
18	—	—	0.53
20	4.62	3.00	0
Total	730.	769.	43.0
D. q_1 (m)	10.5	9.7	14.1
D. q_2 (m)	12.6	11.4	15.9
D. q_3 (m)	16.2	14.2	17.5
L. u. l. (%)	1.2	2.4	—
L. q_1 (%)	0.60	0.43	3.1
L. q_2 (%)	0.37	0.29	2.4
L. q_3 (%)	0.24	0.18	1.6
T. u. l. (°C)	15.2	21.6	—
T. q_1 (°C)	11.2	12.0	13.5
T. q_2 (°C)	10.3	10.9	13.1
T. q_3 (°C)	9.1	9.8	12.7

15.2°C; l.i.=1.2% at 11.30 A.M. and 0.67% at 2.30 P.M.). In Lake Nisi it was distributed in a stratum between the depths of 15 and 18 m. (temp.=13.4—12.5°C; l.i.=2.4—1.6%).

Acanthodiaptomus pacificus var. *yamanacensis* and *Daphnia longispina* were found in the surface catches of the plankton from various lakes, when the water temperature in the epilimnion was lower than 22°C (cf. KIKUCHI, 1927; UENO, 1933, 1934, 1936).

IV. Changes in Vertical Distribution of Plankton in Daytime

For ascertaining the change in the vertical distribution of the plankton at different hours in the daytime, five series of plankton catches were made in Lake Kizaki on August 4, 1935. The results obtained were as in Tables XIII–XVIII.

The change in the intensity of the solar radiation in air during the course of the day is given graphically in Fig. 6. At 3.55 A.M. the day dawned and the sun rose at 5.30 A.M. The sky was clear until 6.30 A.M. and thence until 8.15 A.M. the sun was obscured by clouds. Thereafter the sun shone brightly until sunset, though it was occasionally obscured partially by high clouds. The daily change in the temperature of the surface water was confined within 1.6°C and no internal seiches was observed.

The vertical distribution of the plankton at different hours of the day is drawn in Fig. 7, with the lines of equal light intensity in

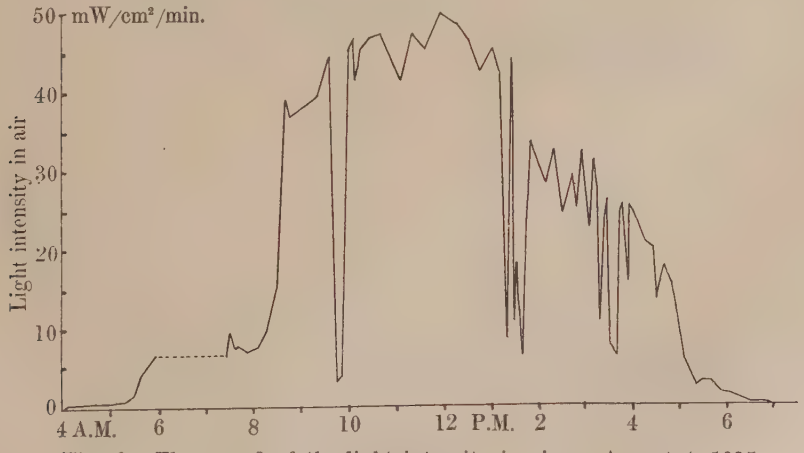

Fig. 6. The record of the light intensity in air on August 4, 1935 at Kizaki.

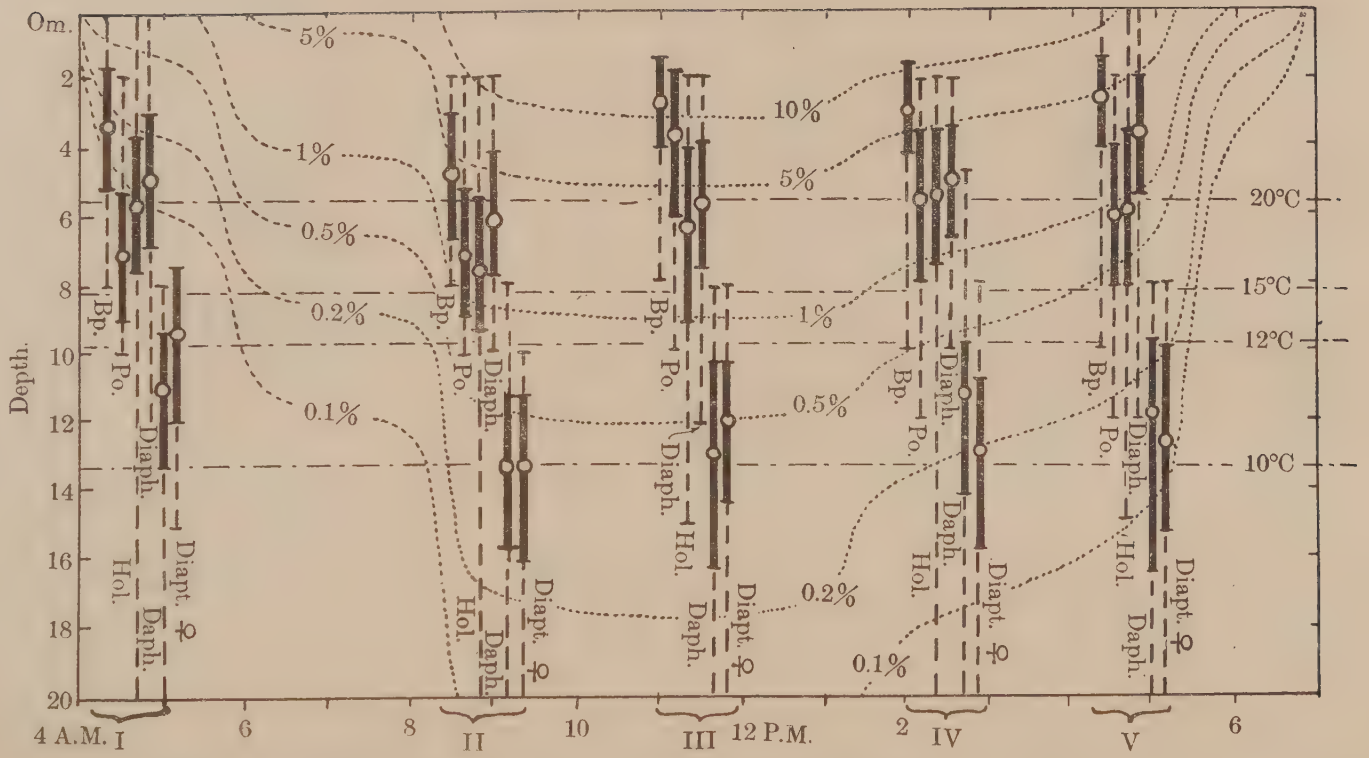

Fig. 7. The change in the vertical distribution of the plankton on August 4, 1935 in Lake Kizaki. The change in the underwater illumination is indicated by the dotted lines, representing the depth at which 10%, 5%, 1%, etc. were demonstrated. Abbreviations as in Table XIV and Fig. 4.

Table XIII. Changes in the number of individuals of plankton at the surface in Lake Kizaki from 2.05 A.M. to 7.00 A.M. on August 15, 1934

Time (A.M.)	2.05	3.20	4.05	4.45	5.30	6.00	6.30	7.00
L. i. (mW)	0.0	0.0	0.3	1.0	11.4	12.6	21.0	22.3
Bosminopsis	0.43	0.53	0.40	**1.33**	0.05	0.04	0.08	0.04
Polyphemus	0.13	0.11	0.20	0.40	**1.73**	**5.34**	0.01	0.47
Holopedium	2.27	4.87	9.08	3.47	3.74	0.27	0.60	**2.67**
Diaphanosoma	2.54	2.07	1.73	0.11	0.04	0.12	0.05	0.13

the water. From this the light intensity, to which the animals are subjected during the course of the day, may be readily demonstrated.

The first series of the plankton catches was made at 4.30 A.M., when the light intensity in air was 0.8 mW. and that at a depth of 1 cm. below the surface was 0.6 mW. or 0.8% of 80 mW. These plankton catches offer the fact that the swimming speed of the animal and the duration of the swimming movement play an important rôle in controlling the vertical distribution, when the light intensity is changing. A marked tendency towards the downward movement of *Acanthodiaptomus*, a strong swimmer, was observed, while a very slight indication of the upward movement was discerned in the cases of *Bosminopsis, Polyphemus, Holopedium* and *Diaphanosoma*. The surface catches made in 1927 (cf. KIKUCHI, 1930) and in 1934 (Table XIII) showed that the maximum abundance of *Bosminopsis* at the surface was attained at 4.30–4.45 A.M., that of *Polyphemus* at 5.30–6.00 A.M., and that of *Holopedium* at 7.00 A.M. This tendency towards the upward movement at dawn was observed by some investigators such as JUDAY (1902), RUTTNER (1905), HARADA (1934) and CLARKE (1934). *Cyclops* was uniformly distributed from the surface to the bottom. *Daphina* was found to have a vertical range below the thermocline.

The second series of the plankton catches was made at 8.45 A.M., when the light intensity in air was 36.6 mW. and that at a depth of 1 cm. below the surface was 22.8 mW. or 28.5% of 80 mW. At this time all the plankton exhibited a marked tendency towards the downward movement and no individual was taken in the surface layer. The median of the population of *Bosminopsis* was found at a depth of 4.8 m., where the light intensity was 4.4%; that of *Polyphemus* at

Table XIV. The vertical distribution of plankton in Lake Kizaki at 4.45 A.M. on August 4, 1935

Bp., Bosminopsis deitersi; Po., Polyphemus pediculus; Hol., Holopedium gibberum; Dia., Diaphanosoma brachyurum; Lept., Leptodora Kindtii; Bm., Bosmina longirostris; Daph., Daphnia longispina; Cycl., Cyclops strenuus and *Cyclops vicinus; Acanthodia., Acanthodiaptomus pacificus* var. *yamanacensis;* Cop., Copepodid; F., Female; M., Male.

	Bp.	*Po.*	*Hol.*	*Dia.*	*Lept.*	*Bm.*	*Daph.*	*Cycl.*	*Acanthodia.*		
									Cop.	F.	M.
0 m.	1.40	0	0.80	4.69	0	0.27	0	2.55	0	0	0
2	1.53	0.07	3.00	7.37	0	0.33	0	3.33	0.13	0	0
5	1.53	0.94	10.4	16.1	0	0.40	0	1.80	0.73	0	0
8	0.13	1.20	8.71	7.71	0	0.47	3.33	0.47	5.70	2.00	1.33
10	0	0.94	1.53	1.14	0	0.67	9.05	0.40	1.80	0.67	1.20
12	0	0	0.33	0.33	0	0.67	5.02	1.33	1.00	0.80	0.67
15	0	0	0.13	0	0	0.53	2.48	1.00	0.20	0.33	0.13
20	0	0	0.07	0	0	0.47	2.33	1.41	0	0	0
Total	102.	77.8	674.	938.	0	97.5	537.	283.	234.	96.7	79.3
D. q_1 (m)	1.8	5.5	3.8	3.0	—	—	9.4	—	6.4	7.4	8.0
D. q_2 (m)	3.4	7.3	5.8	5.0	—	—	11.4	—	8.2	9.4	9.6
D. q_3 (m)	5.1	9.0	7.6	6.9	—	—	13.5	—	9.7	12.0	11.5
L.i. u.l. (%)	0.80	0.38	0.80	0.80	—	0.80	0.03	0.80	0.38	—	—
L.i. q_1 (%)	0.40	0.10	0.19	0.26	—	—	0.02	—	0.07	0.04	0.03
L.i. q_2 (%)	0.22	0.04	0.09	0.11	—	—	0.01	—	0.03	0.02	0.02
L.i. q_3 (%)	0.11	0.03	0.04	0.05	—	—	0.01	—	0.02	0.01	0.01
L.i. l.l. (%)	0.03	0.02	—	0.01	—	0.01	0.01	0.01	0.01	0.01	0.01
T. q_1 (°C)	25.8	20.5	23.3	24.3	—	—	12.6	—	18.7	16.5	15.2
T. q_2 (°C)	23.6	16.8	19.9	21.6	—	—	10.9	—	14.8	12.6	12.2
T. q_3 (°C)	21.4	13.4	16.0	17.6	—	—	10.1	—	11.0	10.6	10.8

7.2 m. (l.i.=1.4%); that of *Holopedium* at 7.6 m. (l.i.=1.3%); that of *Diaphanosoma* at 6.1 m. (l.i.=2.9%); and that of *Cyclops* at 8.5 m. (l.i.=1.1%). The vertical distribution of *Acanthodiaptomus* and *Daphnia* was confined to the meta- and hypolimnion.

The third series of the plankton catches was made at 11.30 A.M. when the light intensity in air was 45.5 mW. and that at a depth of 1 cm. below the surface was 23.7 mW. or 29.6% of 80 mW. All the plankton showed a tendency to the upward migration, contrary to

Table XV. The vertical distribution of plankton in Lake Kizaki at 8.45 A.M. on August 4, 1935

	Bp.	*Po.*	*Hol.*	*Dia.*	*Lept.*	*Bm.*	*Daph.*	*Cycl.*	*Acanthodia.*		
									Cop.	F.	M.
0 m.	0	0	0	0	0	0	0	0	0	0	0
2	0.67	0.33	1.33	1.00	0	0	0	0.87	0	0	0
5	2.20	1.20	3.33	12.0	0.07	0.13	0	1.73	0	0	0
8	0.20	2.67	11.3	10.3	0	0.53	0.73	1.07	1.80	0	0.07
10	0	1.40	5.47	1.53	0	0.33	6.66	3.40	3.13	0.33	0.87
12	0	0	0.53	0	0	0.33	9.00	0.67	3.07	1.00	1.53
15	0	0	0.33	0	0	0.20	6.33	0.20	0.73	0.53	0.20
20	0	0	0.13	0	0	1.73	3.00	0.33	0.33	0.40	0
Total	87.8	139.	555.	663.	—	80.4	705.	201.	222.	72.9	65.0
D. q_1 (m)	3.2	5.4	5.8	4.3	—	—	11.2	5.2	9.2	11.2	10.5
D. q_2 (m)	4.8	7.2	7.6	6.1	—	—	13.4	8.5	11.1	13.2	11.9
D. q_3 (m)	6.7	9.0	9.3	7.6	—	—	15.8	10.8	13.5	16.0	13.7
L. i. u. l. (%)	14.	14.	14.	14.	—	4.2	1.1	14.	1.1	0.63	1.1
L. i. q_1 (%)	8.6	3.6	3.3	5.4	—	—	0.86	4.0	0.87	0.49	0.57
L. i. q_2 (%)	4.4	1.4	1.3	2.9	4.0	—	0.33	1.1	0.50	0.33	0.44
L. i. q_3 (%)	2.0	0.89	0.81	1.3	—	—	0.22	0.57	0.32	0.23	0.32
L. i. l. l. (%)	1.1	0.63	0.13	0.66	—	0.11	0.11	0.11	0.11	0.11	0.26
T. q_1 (°C)	24.0	20.8	19.9	22.6	—	—	11.0	21.2	12.9	11.0	11.2
T. q_2 (°C)	21.9	16.9	16.0	19.3	—	—	10.2	14.3	11.1	10.7	11.0
T. q_3 (°C)	18.0	13.3	12.8	16.0	—	—	9.2	11.1	10.1	9.2	10.1

the increase in light intensity, and it was strongly marked in the cases of *Bosminopsis* and *Polyphemus*. The median of the population of *Bosminopsis* ascended to a depth of 2.7 m. (l.i.=11%); that of *Polyphemus* to 3.7 m. (l.i.=7.3%); that of *Holopedium* to 6.3 m. (l.i.=2.7%); that of *Diaphanosoma* to 5.7 m. (l.i.=3.6%); and that of *Cyclops* to 6.5 m. (l.i.=2.4%). *Acanthodiaptomus* and *Daphnia* showed a slight tendency to ascend, though they still distributed themselves in the meta- and hypolimnion.

A similar tendency to the upward movement can be seen from the vertical distribution of copepodid stage III of *Calanus finmarchicus* taken by CLARKE (1934) at 11.26 A.M., and of *Daphnia longispina*, *Leptodora Kindtii* and *Diaptomus gracilis* at midday observed by

Table XVI. The vertical distribution of the plankton in Lake Kizaki at 11.30 A.M. on August 4, 1935.

	Bp.	*Po.*	*Hol.*	*Dia.*	*Lept.*	*Bm.*	*Daph.*	*Cycl.*	*Acanthodia.*		
									Cop.	F.	M.
0 m.	0	0	0	0	0	0	0	0.13	0	0	0
2	3.93	1.32	3.89	2.41	0	0.79	0	2.20	0	0	0
5	0.26	0.13	3.96	16.2	0.07	0.99	0	3.66	0.07	0	0
8	0.07	0.26	7.26	10.6	0.07	0.40	0.99	1.14	1.98	0.13	0
10	0	0.20	2.24	1.52	0	0.46	10.9	2.20	4.29	1.33	1.33
12	0	0	0.99	0.07	0	0.07	6.93	1.33	1.20	1.20	0.80
15	0	0	0.07	0	0	0.13	4.95	0.40	0.33	0.47	0.13
20	0	0	0	0	0	0.86	4.62	0.40	0	0.47	0
Total	108.	47.5	468.	844.	3.7	96.7	730.	298.	172.	80.4	51.8
D. q_1 (m)	1.4	1.9	4.0	3.9	4.8	—	10.5	3.7	8.4	10.3	10.0
D. q_2 (m)	2.7	3.7	6.3	5.7	6.2	—	12.9	6.5	9.9	11.9	11.1
D. q_3 (m)	4.0	6.0	8.6	7.5	7.6	—	16.2	10.3	11.5	14.2	12.9
L.i. u. l. (%)	—	—	14.	14.	—	14.	1.2	14.	4.2	1.2	—
L.i. q_1 (%)	17.	14.	6.3	6.6	4.6	—	0.60	7.3	1.1	0.62	0.66
L.i. q_2 (%)	11.	7.3	2.7	3.6	3.0	—	0.37	2.4	0.69	0.46	0.53
L.i. q_3 (%)	6.3	3.3	0.96	1.4	1.4	—	0.24	0.62	0.50	0.32	0.37
L.i. l. l. (%)	1.2	0.66	0.26	0.45	—	0.13	0.13	0.13	0.26	0.13	0.26
T. q_1 (°C)	25.8	25.7	23.0	23.1	21.9	—	11.2	23.3	14.5	11.3	11.5
T. q_2 (°C)	24.7	23.3	18.9	20.1	19.1	—	10.3	18.4	11.7	10.7	11.0
T. q_3 (°C)	23.0	19.5	14.1	16.3	16.0	—	9.1	11.4	10.9	9.8	10.3

Southern and Gardiner (1932). Harada (1934) also shows the same tendency in *Diaphanosoma*. Observations made by Russel (1931) and Worthington (1931) prove that some species of the plankton were taken in the strata of higher irradiation in the afternoon than in the early morning.

The fourth series of the plankton catches was made at 2.30 P.M., when the light intensity in air was 26.6 mW., and that at a depth of 1 cm. below the surface was 13.6 mW. or 17.0% of 80 mW. *Bosminopsis* and *Polyphemus* showed a slight tendency to the downward movement, contrary to the decrease in light intensity. The median of the population of *Bosminopsis* descended to a depth of 3.0 m. (l.i.=5.5%); that of *Polyphemus* to 5.7 m. (l.i.=2.0%). A similar tendency towards the

Table XVII. The vertical distribution of the plankton in Lake Kizaki at 2.30 P.M. on August 4, 1935

	Bp.	*Po.*	*Hol.*	*Dia.*	*Lept.*	*Bm.*	*Daph.*	*Cycl.*	*Acanthodia.*		
									Cop.	F.	M.
0 m.	0	0	0	0	0	0	0	0.07	0	0	0
2	10.3	0.80	2.33	2.33	0	0.53	0	2.53	0	0	0
5	2.07	1.20	4.53	30.0	0	0.73	0.13	5.67	0	0	0
8	0.20	0.80	3.33	2.33	0.07	0.53	7.00	1.53	2.67	0.40	0.53
10	0.07	0.47	0.87	0.67	0	0.20	14.0	1.47	4.13	0.67	1.33
12	0	0.20	0.73	0	0	0.27	9.33	1.60	1.47	1.47	1.60
15	0	0	0.07	0	0	0.27	3.07	1.00	0.13	0.80	0.07
20	0	0	0.20	0	0	1.00	3.00	0.53	0	0.20	0
Total	362.	90.4	301.	1030.	—	94.9	797.	395.	191.	91.1	82.5
D. q_1 (m)	1.6	3.5	3.5	3.4	—	—	9.7	3.8	8.2	10.8	9.4
D. q_2 (m)	3.0	5.7	5.6	5.0	—	—	11.4	6.4	9.6	13.1	11.0
D. q_3 (m)	4.2	8.0	7.5	6.6	—	—	14.2	10.7	11.2	15.8	12.7
L.i. u. l. (%)	—	8.2	8.2	8.2	—	8.2	2.4	17.	2.4	0.67	0.67
L.i. q_1 (%)	9.3	4.5	4.5	4.7	—	—	0.43	4.0	0.64	0.32	0.47
L.i. q_2 (%)	5.5	2.0	2.1	2.4	0.67	—	0.29	1.5	0.44	0.20	0.31
L.i. q_3 (%)	3.4	0.67	0.79	1.3	—	—	0.18	0.33	0.30	0.14	0.22
L.i. l. l. (%)	0.38	0.26	0.07	0.38	—	0.07	0.07	0.07	0.15	0.07	0.15
T. q_1 (°C)	25.8	23.6	23.6	23.7	—	—	12.0	23.1	14.8	11.1	12.6
T. q_2 (°C)	24.3	20.1	20.3	21.6	—	—	10.9	18.7	12.2	10.0	11.0
T. q_3 (°C)	22.7	15.2	16.3	18.2	—	—	9.8	11.2	11.0	9.3	10.4

downward movement in the afternoon can be noticed from observations made by SOUTHERN and GARDINER (1932) and CLARKE (1934). The other species showed a very slight tendency to the upward movement, though they ascended more slowly than the lines of equal light intensity did. The median of the population of *Holopedium* was found at a depth of 5.6 m. (l.i.=2.1%); that of *Diaphanosoma* at 5.0 m. (l.i.=2.4%); and that of *Cyclops* at 6.4 m. (l.i.=1.5%).

The fifth series of the plankton catches was made at 4.45 P.M., when the light intensity in air was 15.7 mW. and that at a depth of 1 cm. below the surface was 9.0 mW. or 11.3% of 80 mW. The upward migration of *Bosminopsis* and *Diaphanosoma* had been inaugulated, and some of them were found in the surface catch, while *Polyphemus*,

Table XVIII. The vertical distribution of the plankton in Lake Kizaki at 4.45 P.M. on August 4, 1935

	Bp.	*Po.*	*Hol.*	*Dia.*	*Lept.*	*Bm.*	*Daph.*	*Cycl.*	*Acanthodia.*		
									Cop.	F.	M.
0 m.	0.13	0	1.33	1.87	0	0	0	1.00	0	0	0
2	8.00	1.07	3.33	20.7	0	0.53	0	1.00	0	0	0
5	0.67	2.67	4.20	8.33	0.07	1.00	0	2.67	0.07	0	0
8	0.07	2.20	6.00	3.67	0	0.93	6.33	1.67	5.20	0.53	0.40
10	0.07	1.13	1.80	0.93	0	0.67	13.7	1.60	4.47	0.80	0.87
12	0	2.20	0.20	0.33	0	0.33	8.33	1.33	1.20	0.87	0.53
15	0	0	0.13	0	0	0.87	4.06	0.67	0.13	0.87	0.33
20	0	0	0	0	0	1.67	4.33	1.20	0	0.07	0
Total	225.	189.	419.	905.	—	165.	911.	275.	257.	87.6	53.8
D. q_1 (m)	1.4	4.0	3.5	2.0	—	—	9.6	—	7.4	10.0	9.2
D. q_2 (m)	2.7	6.1	6.0	3.6	—	—	11.9	—	9.0	12.6	11.2
D. q_3 (m)	4.0	8.2	8.1	5.2	—	—	16.4	—	10.5	15.3	13.7
L.i. u. l. (%)	11.	5.4	11.	11.	—	11.	0.44	11.	1.6	0.44	0.44
L.i. q_1 (%)	6.5	2.4	3.0	5.4	—	—	0.29	—	0.54	0.25	0.33
L.i. q_2 (%)	4.0	1.1	1.2	2.9	1.6	—	0.17	—	0.35	0.15	0.20
L.i. q_3 (%)	2.4	0.42	0.43	1.5	—	—	0.08	—	0.22	0.10	0.12
L.i. l. l. (%)	0.3	0.17	0.10	0.17	—	0.05	0.05	0.05	0.10	0.05	0.10
T. q_1 (°C)	25.8	23.0	22.6	25.7	—	—	12.2	—	16.5	11.5	12.9
T. q_2 (°C)	24.7	19.3	19.5	22.5	—	—	10.7	—	13.3	10.4	11.0
T. q_3 (°C)	23.0	14.8	15.0	21.2	—	—	9.0	—	11.2	9.5	10.1

Daphnia and *Acanthodiaptomus* still remained in the deeper strata. A considerable number of *Holopedium* and *Cyclops* were found in the surface catches, though the majority were distributed in the deeper strata. The median of the population of *Bosminopsis* was found at a depth of 2.7 m. (l.i.=4.0%); that of *Polyphemus* at 6.1 m. (l.i.=1.1%); that of *Holopedium* at 6.0 m. (l.i.=1.2%); and that of *Diaphanosoma* at 3.6 m. (l.i.=2.9%).

Bosmina was found to keep off the surface layer during the daytime and was uniformly distributed in the deeper strata.

V. Summary

1) The vertical distribution of *Bosminopsis deitersi*, *Polyphemus*

pediculus, *Holopedium gibberum*, *Diaphanosoma brachyurum*, *Leptodora Kindtii* is much closely correlated with the light intensity but not with the water temperature.

2) The vertical distribution of *Cyclops strenuus* and *Bosmina longirostris* is roughly correlated with the light intensity.

3) In the case of *Acanthodiaptomus pacificus* var. *yamanacensis* both the water temperature and light intensity should be regarded as the factors controlling the vertical distribution, when the water temperature in the epilimnion is higher than 22°C.

4) The vertical distribution of *Daphnia longispina* is more closely correlated with the water temperature than with the light intensity, when the water temperature in the epilimnion exceeds 22°C.

5) The swimming speed and the duration of the swimming movement, when the light intensity is changing, are some important factors controlling the vertical distribution of the plankton.

6) All the plankton are found to frequent a higher level at midday than in the early morning and are subjected to higher irradiation.

7) *Bosminopsis deitersi* and *Polyphemus pediculus* show a slight tendency to the downward movement in afternoon in spite of the decrease in light intensity, while *Holopedium gibberum* and *Diaphanosoma brachyurum* exhibit a tendency to move upwards.

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Further Notes on Brachyuran Larvae

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(With 4 Tables and 36 Text-figures)

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Literature

The writer has already described the zoeas of some Japanese crabs together with the undetermined zoeas that were collected among plankton, and discussed their larval characters to enable their determination (Aikawa, 1929, 1933). Since then zoeas of thirty more species have been reared from berried crabs, and the writer here has again attempted to define the larval characters of some of the important families, including zoeas of Japanese crabs as well as those of foreign countries. It seems almost impossible to classify zoeas by their features alone as is done in the case of adults, because the larva, besides its simple construction, undergoes marked changes through metamorphosis a number of times. The writer shows, nevertheless, that zoeas can be classified very satisfactorily as a rule by the characters of the 2nd antenna and telson, the presence or absence of carapacial spines, and by the hair formula. From these features it is possible to determine the genera or even the species to which a zoea belongs, although in some cases neither genera nor even family can be determinable. In the latter case, pigmentations of the maxillipedes and the abdominal somites are useful characters, although hardly any author seems to have so far concerned himself with chromatophores.

Furthermore, the writer attempts to ascertain whether or not these larval characters have any phylogenic significance and whether or not the grouping of zoeas in accordance with these characters is a natural one. Lastly, a key to some of the important families has been

constructed and applied in determining zoeas that have previously been described.

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Part I. The larval characters of zoea

1. The 2nd antenna (Fig. 1). The 2nd antenna of all crustacean larvae is generally a permanent feature. In the 1st larval stage of all macruran and anomuran larvae, the 2nd antenna has a single basal part, flagellum (endopodite), and scale (exopodite). The scale, which is foliaceous, has no trace of segmentation, and bears some densely plumose hairs around it. Throughout its whole larval stage (Fig. 1, 1–3), this does not undergo any marked change. The flagellum, which is smaller than the scale, is peduncular. Its proximal part is only pointed or armed with teeth, or sometimes tipped with plumose setae or with short strong spinules. The endopodite, which is segmented, also changes in appearance during metamophosis. The basal part usually bears 1 or 2 small spinules on its distal edge, its structure also remaining unchanged even in the final larval stage. The 2nd antenna is of the same type in all macruran and anomuran larvae, at least in the first larval stage. The 2nd antenna of both macruran and anomuran larvae differs from that of brachyuran zoea in the following points: (1) one of the spinules on the basal part develops into a large peduncle and becomes an important part of the brachyuran antenna, (2) the foliaceous exopodite is much reduced and has a simple spinous process, not differing from the peduncle, and (3) the endopodite is usually absent in the 1st larval stage of brachyuran larva, although it

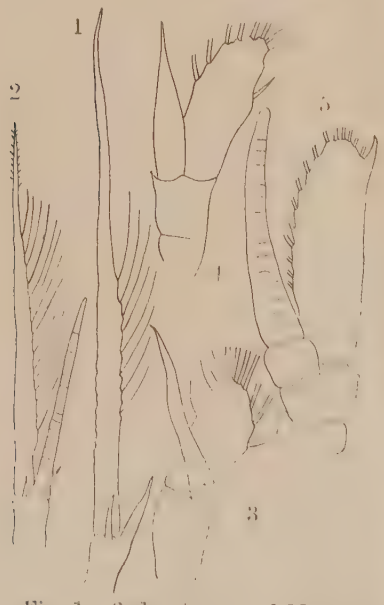


Fig. 1. 2nd antennae of Macrura and Anomura

1. *Galathea rugosa* 1st stage
2. „ last stage
3. *Hippolyte varians* 1st stage
4. „ 2nd stage
5. „ 4th stage

attains to considerable length at a later stage. The difference in the brachyuran antenna from those of macruran and anomuran larvae however becomes indistinct owing to the presence of certain transitional types of antenna. The spinule on the basal part, which is usually very small in the macruran larva, becomes more or less distinct in anomuran larvae, such as *Galathea* and *Lithodes*, attains medium length in the larvae of the Homolidae, and becomes very long in the zoeas of Brachyura. The endopodite, which is always present and very large in the macruran larva, is very small or even absent in some larvae of Anomura, as in *Galathea rugosa*. All macruran larvae have well developed, flattened, and foliaceous exopodites. This has been observed in the larva of *Galathea rugosa*, in which it is long and peduncular, resembling that of the brachyuran larva, although it is still provided with plumose hairs around it. In the brachyuran larva, the single peduncular exopodite is covered by a foliaceous sheath at the prezoeal stage, just after hatching. A similar transformation is thus traceable through its ontogenetic development. Although both the exopodite and the endopodite of macruran and anomuran antennae are gradually reduced toward the brachyuran antenna, in contrast to it, the small spine of the basal part increases in size from Macrura to Brachyura. Cano regarded the long exopodite as a primitive feature, it being homologous to the antennal scale of Caridea (Cano, 1892; cited from Lebour, 1928).

Of the 2nd antenna, the exopodite is most developed in type A of antenna, reduced considerably in type B, and wholly disappeared in type C. Comparing the degrees of exopodite development, type A is probably the most primitive, type C highly developed, and type B intermediate between the two. Type D may be a mere deviation. They can thus be arranged in stages of development. Actually, type A is found among the Oxystomata, types A and B among the Majoidea, and all the three types in Cancroidea. Type C, the most developed, occurs in the most highly developed group, and type A, the most primitive, in the much lower group. The D-type of antenna is found widely distributed in several groups, zoeas with antenna of this type belonging to families that are supposed to have deviated from their allied families.

2. Telson (Fig. 2). Compared with the relative uniformity of the 2nd antenna, the larval telsons of Macrura and Anomura comprise several types. As the six principal types we may mention the telsons of *Penaeus, Pasiphaë, Pandalus, Astacus,* and *Porcellana*. In Macrura

and Anomura, the larval telson in the early stage differs from that in the later mysis stage. The writer, following GURNEY, mainly refers to telson in the 1st larval stage, seeing that the early larva retains the primitive features, while later, development is retarded more or less as the result of early acquisition of adult characters (GURNEY, 1927).

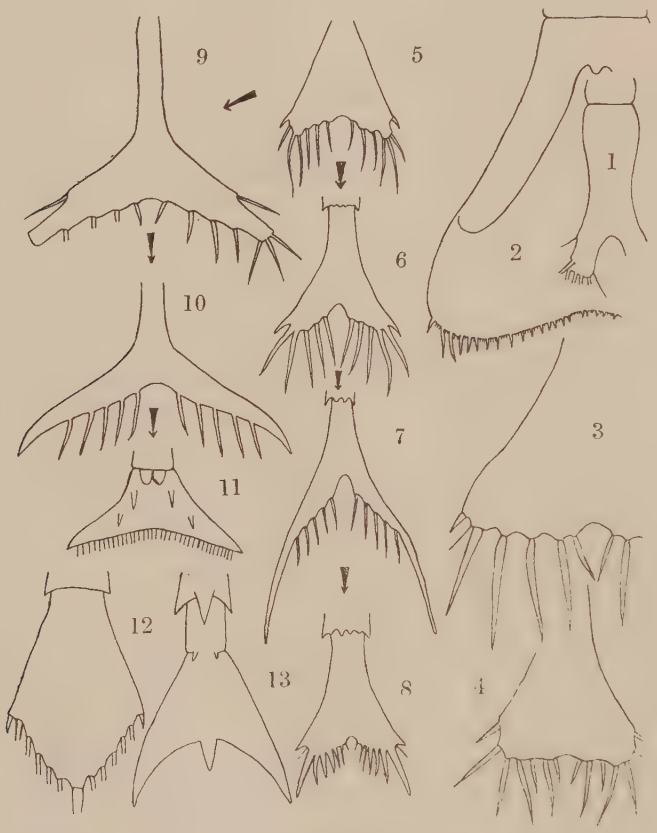


Fig. 2. Telsons of Macrura and Anomura at 1st stage

1. *Penacus* sp.
2. *Pasiphaë tarda*
3. *Gebia littolaris*
4. *Hippolyte varians*
5. *Pandalus propinquus*
6. *Galanthea dispersa*
7. *Galathea rugosa*
8. *Lithodes maia*
9. *Crangon norvegicus*
10. *Taxea noctura*
11. *Homola* sp.
12. *Porcellana longicornis*
13. *Astacus americanus*

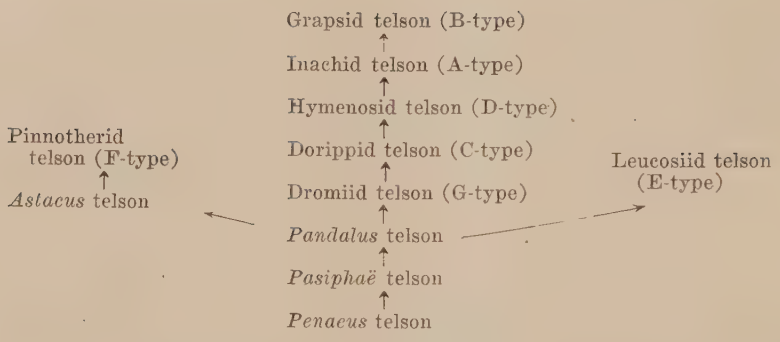
The type differences in these larval telsons are as follows: The *Penaeus* telson (*Penaeus* sp. Fig. 2, 1) has 2 quadrate lobes, greatly resembling

that of Copepods. With these lobes expanded and the middle emargination consequently shallow, this telson becomes the larval telson of *Pasiphaë* (*Pasiphaë tarda,* 2). This *Pasiphaë*-telson can also be correlated with the B- and C-types of the brachyuran telson, being related through such transitional telsons as observed in the 1st larval stage of *Gebia littolaris* (3), *Hippolyte varians* (4), *Pandalus propinquus* (5), *Galathea dispersa* (6), *G. rugosa* (7), and *Lithodes maia* (8). These transitional types of telson will be referred to here as the *Pandalus* telson. On the other hand, *Pasiphaë* telson can also change to telsons of Dromiidae and Homolidae, and even to that of the Leucosiidae, following the course of transition from *Pandalus* telson (*Pandalus propinquus*) to *Taxea nocturna* through *Crangon norvegicus* (13). The telson of *Astacus americanus* (13), which has a median spine, resembles the F-type telson of the Pinnotheridae. Through the telson of *Callianassa, Calocaris macandreae,* and *Axius stirhynchus,* this telson of *Astacus* is also related to the *Pandalus* telson. In *Crangon,* the mysis has a telson with a median spine (*Astacus* type of telson), while the zoea has a *Pandalus* type of telson. It is also noteworthy that the D-type of telson in the Hymenosomidae does not resemble any telson in the 1st larval stage of Macrura and Anomura, but resembles instead those at the mysis stage of the last two.

Porcellana telson (*Porcellana longicornis,* 12) is also related to *Pandalus* telson through those of *Pagurus chiroacanthus, Palaemon fabricii,* and lastly *Pandalus propinquus.*

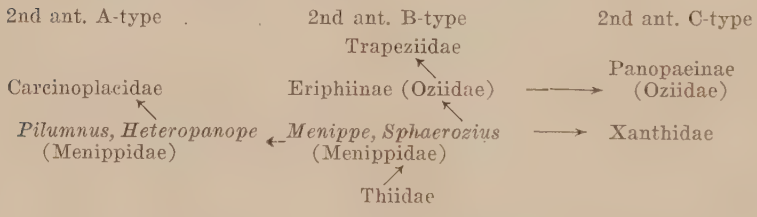
In this way, decapod larval telson of whatever type are communicated by the transitional types of telson to primitive types, so far as concern the larval stage, so that with any telson, it is possible to postulate a still more primitive type. None of them are therefore independent of the series of decapod transformations.

Among the Dromiidae and the Homolidae is a G-type of telson that resembles most the *Pandalus*-type. We find both types E and C among the Oxystomata, types A and D among the Majoidea, and type B among the Catametopa. Type F is also found among the Pinnotheridae of the Catametopa. Type G resembles therefore the fundamental *Pandalus*-type and is also most primitive, while types C and E are slightly more developed, ranking next to the *Pandalus*-type. The B-type of telson is most highly developed, while the A- and D-type may be the intermediate. The relationships between these types may be assumed to be as in the following scheme:

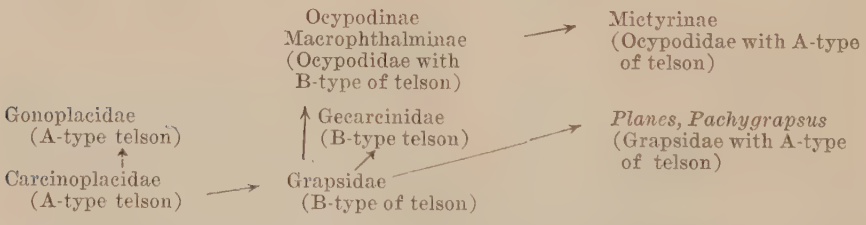


There occur simultaneously several types of telson and 2nd antenna in a small limited group, for example, in the larvae of the Xanthini and Grapsini.

(1) Xanthini....Telson always A-type.



(2) Grapsini.



From the fact that the adult diverges increasingly from its ancestoral form, the conclusion is that type A of the 2nd antenna can transform to type B, and eventually to type C. In addition, the B-type of telson usually dominates more in the highly developed group Grapsini than in the less developed Xanthini. The phylogenic development of the 2nd antenna can not only be traced by comparing those of all decapods at the 1st larval stages, but is also found on a smaller scale in these limited groups. The differences in the degree of development is almost always parallel to the phylogenic relationships between their adult forms.

3. Phylogenic significance of the 2nd antenna and telson. In view of the successive changes in structure of both the 2nd antenna and telson from Macrura to Brachyura, it may safely be said that the 2nd antenna and telson retain their ancestral characters preserving the phylogenic significance, although opinions differ on the relative importance of the secondary larval characters.

Heider, following Claus, regarded the zoea as an interposed larval form that does not belong to the direct series of transformation in the Malacostraca, seeing that it has assumed a certain independence because of the secondary changes in structure, chief of which is the retarded development of the hind thoracic region. The zoea, which is thus regarded as a secondary modified larval form related to the peculiar conditions of larval life, cannot be classed with the series of hypothetical ancestors of the Malacostraca. R. Daniel (1930) in discussing the significance of the persistence of the adult type of muscular system in the larval form, arrived at the same conclusion. The presence of the adult abdominal muscular system of *Crangon vulgaris* in its zoea may support Claus view that this larval form has no ancestral significance, since it means that, in addition to the external secondary modification to the larval life, there is also present a complicated system that is typical of the adult. There is also the adult system of masculature in the mysis stage, which is generally accepted as representing a schizopod ancestor. The presence of the adult system in these larval forms can be explained by its being due to the simplification in metamorphosis by the tendency toward obliteration of characteristics of the special ontogenetic stages. Zoea stage appears altered by anticipating certain peculiarites in the ensuing stages. Development is hindered by early acquisition of adult characters. Daniel also says that the occurrence of the adult system of masculature in zoea and mysis is additional indication of this gradual suppression of the complicated larval series in the higher crustacea.

However, if this conclusion is accepted, the author is of the opinion that the anticipation is necessarily qualified by the original nature of the larval characters. Consequently, if the larval characters are affected by secondary modification and if they show precocious development, they possess ancestral significance to a considerable extent. Claus also pointed out that the segments in the middle region of the body in zoea are not altogether wanting, although being compressed they are difficult to recognize externally, so that, as might be supposed,

the way in which the segment forms is not so opposed to that of other larvae of Entomostraca and Malacostraca. This point therefore might not deter one from accepting BALFOUR's view that the zoea is an ancestral form, since a true zoea is found in all those Malacostracan group in which the larva leaves the egg in an imperfect form. The unity of plan here expresses a relationship just as strongly as it does in adult forms. Certain features can at any rate indicate ancestral structure, although there may occur some modifying tendencies that obscure the ancestral significance.

Should the zoeal features, as a whole, not retain the ancestral characters, it is certainly possible to select from them some features of phylogenic significance. These characters may be useful in determining the zoeas and in tracing the relationship between their adult forms. The muscular system and the number of segments, as CLAUS and DANIEL noticed, may not be suited for this purpose.

The present writer is convinced that the 2nd antenna and telson may have phylogenic significances, seeing that they show direct series of transformations from Macrura to Brachyura, and which, in addition, are traceable ontogenetically.

4. Other larval features. Zoeas of the same or nearly allied families are also similar in other faeatures. HYMAN noted that pigmentation, being a constant feature, is often of diagnostic value, although the earlier paper does not refer to it except in the most general terms (HYMAN, 1925). Zoeas differ from one another in character and in the grouping of chromatophores in the maxillipedes. In the primitive group, the maxillipedal chromatophores are generally of primary character, while in the higher group they are secondary. The hair formula, especially the modes of serration on the endopodites of both maxillae, are also peculiar to each group. The endopodite of the 2nd maxilla is 2-jointed in the most primitive group, such as the Dromiidae, while it is bifurcated in the higher group. In the matter of presence or absence of carapacial spines, there is a similarity among the zoeas of the same group, although the grouping based on it is not always parallel to the relationship between their adult forms. Neverthless, it is possible to detect the successive changes in disappearance or development of spines among the nearly allied groups. For example, in the development of the lateral spines, the zoea of *Herbstia* is intermediate between the 1st and 2nd groups of the Majidae, as mentioned in (9), Part III.

Part II. Description of zoeas newly obtained

1. *Latreillia phalangium* DE HAAN. 1st zoea. Fig. 3.

Characters: Only rostrum present; 2nd ant. E-type; telson G-type; no stable brown chromatophore present in maxilliped and adbomen; hair formula 5–1, 3–4 (7), 5–2–0–0.

Rostrum 0.85 mm, carapace 0.53 mm; abdomen 0.85 mm long, 0.21 mm wide, telson 0.23 mm.

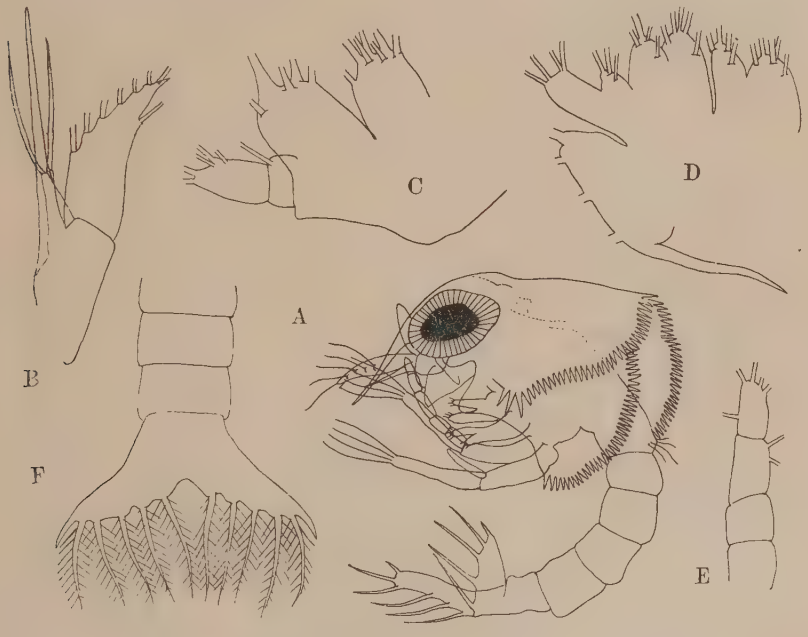


Fig. 3. *Latreillia phalangium* D. HANN. 1st larva.
(A) lateral view × 61. (B) 2nd ant. × 120. (C) 1st mx. × 233. (D) 2nd mx. × 233. (E) enp. of 2nd mxp. × 233. (F) abdomen × 61.

Zoea resembles larvae of Macrura and Anomura. Lateral part of carapace double lapped, both laps closely toothed along their lower margins; teeth fairly large in part of upper lap where the lateral spine is usually expected in other brachyuran zoea. Both laps unite behind. 1st ant. of usual form; 2nd ant. E-type. Foliaceous enp. tipped with small tooth, with 8 densely plumose hairs around it. Enp. short, attaining only half the length of exp., ending in 2 spinules. Spinous process (peduncle) very long, nearly twice length of enp. and equal to exp. In this way, E-type of 2nd ant. can be distinguished from the

usual macruran antenna. Enp. of 1st mx. 2-articulate, mode of serration here expressed by 5–1. Enp. of 2nd mx. has 2 joints, its proximal joint with 4 hairs, distal joint with 3. Other podites well bifurcated. Scaphognathite similar to usual brachyuran ones, with 4 long plumose hairs along lateral side, ending in pointed projection. 1st mxp. similar to those observed in usual brachyuran zoea, while 2nd mxp. has 4-jointed enp. 1st and 2nd joints hairless, 3rd 2, distal 4 each. No lateral knob on abdomen, but 2 long dorsal hairs on 1st somite. Size of all abdominal somites similar, wider than long. Telson G-type, resembling that of *Crangon norvegicus* (fig. 2, 5) or *Taxea nocturna* (6). Short but strong tooth present on corner and lower margin concave. 4 pairs of spines of same length, plumose. Middle depression fairly deep.

2. *Parahomola japonica* Parisi. 1st zoea. Fig. 4.

Characters: All similar to *Latreillia phalangium*, except hair formula 5–1, 6–2 (8), 5–2–1–1.

Rostrum 0.55 mm, carapace 0.79 mm; abdomen 0.98 mm long, 0.22 mm wide, telson 0.30 mm.

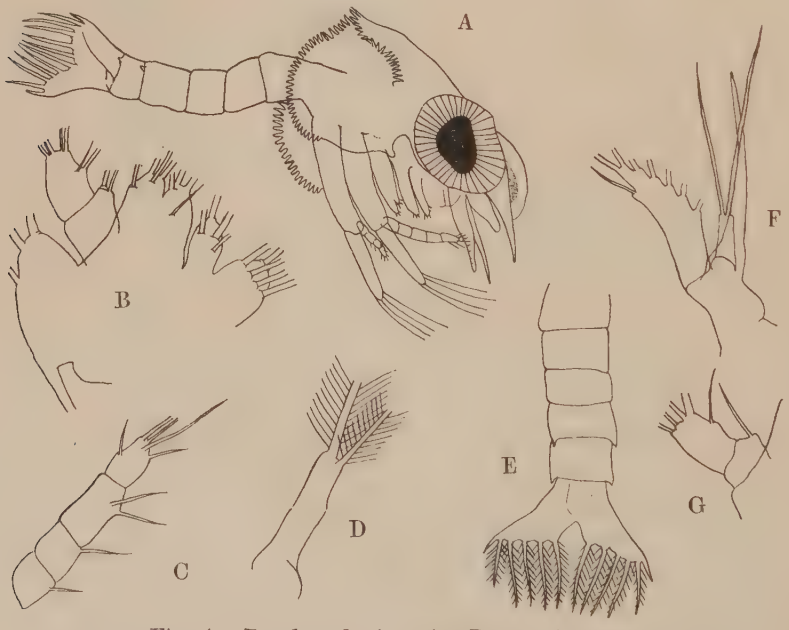


Fig. 4. *Parahomola japonica* Parisi. 1st zoea.
(A) lateral view × 40. (B) 2nd mx. × 213. (C) enp. of 2nd mxp. × 213.
(D) enp. of 2nd ant. × 213. (E) abdomen × 39. (F) 2nd ant. × 87.
(G) enp. of 1st mx. × 213.

This zoea resembles in every respect that of *Latreillia phalangium*. Carapace also double, although upper lap not so expanded as in *Lat. phal.*, toothed along their margins. 2nd ant. has no tooth on tip of exp., but in other points same as that of *Lat. phal.* Enp. of 1st mx. also similar to *Lat. phal.*, while enp. of 2nd mx. differs in mode of serration, 6–2 (8), from *Lat. phal.* Scaphognathite has only 3 lateral hairs, being 1 less than *Lat. phal.* Enp. of 2nd mxp. has also 4 joints. Both 1st and 2nd joints with 1 hair each, 3rd 2, distal 5. No lateral knob on abdominal somite. Lateral ends of 4th and 5th somites slightly pointed. 4 pairs of inner spines, middle depression slightly deeper in this larva than in *Lat. phal.*

3. *Homola* sp. 4th zoea to megalopa. Fig. 5.

Characters: Only rostrum present, but very short; in addition a single median horn and paired sublateral ones in frontal region, 2nd ant. E-type, telson G-type, hair formula 5–1, 2–4 (6), 5–3–1–3–0.

Large zoeas of 4th stage and a megalopa were collected in Sagami Bay on September 12, 1933. Rostrum short, thick, pointed. Lateral and median horns also short, thick, branched. Lateral horns projecting in direction perpendicular to median horn. Carapace large and double lapped as seen in *Latreillia* and *Parahomola*. Both laps toothed along their lower margins. Many thick hairs on middle dorsal part, some tubercles on postero-dorsal part. 1st ant. usual form. At 4th zoeal stage, basal part 2-jointed, enp. single, exp. incompletely 5-jointed. 2nd ant. E-type. Peduncle much shorter than observed in larvae of *Parahomola* and *Latreillia*. Exp. slender, bearing 12 long plumose hairs along inner side, 7 along outer, but no tooth on tip. Enp. nearly same length as exp., but not yet segmented at last stage. Comparison of antennae of these 3 species shows 2nd ant. of *Homola* sp. most primitive in character, although distinguished from usual macruran antenna by fairly long spine on basal part. Mandible has wide chewing surface, haired along outer margin. Palp single joint. Enp. of 1st mx. has 2 joints; 1st joint has 1 hair on distal edge, the 2nd 1 lateral and 4 terminal hairs. Coxo- and basipodites of 2nd mx. deeply bifurcated, all lobes densely serrated. Enp. has 2 joints. 1st joint has 1 hair, 2nd has 4 each. Scaphognathite fairly large, closely serrated all around its margin. Expds. of both 1st and 2nd mxpds. has only 6 swimming hairs at last zoeal stage. Enp. of 2nd mxp. has 5 joints. 1st joint hairless, 2nd, 3, 3rd only 1, 4th 4, last 5. 3rd mxp.

Fig. 5. *Homola* sp. Last zoea and megalopa.
(A) dorsal view (megalopa) ×9. (B) lateral view (zoea) ×14. (C) mandible (zoea) ×40. (D) dactylus of last leg (magalopa) ×39. (E) 1st ant. (zoea) ×43. (F) 1st ant. (megal.) ×35. (G) 2nd ant. (zoea) ×43. (H) 2nd ant. (zoea) ×21. (I) 1st mxp. (zoea) ×34. (J) 2nd mxp. (zoea) ×34. (K) 3rd mxp. (zoea) ×61. (L) 1st mxp. (megal.) ×26. (M) 2nd mxp. (megal.) ×26. (N) 3rd mxp. (megal.) ×26. (O) 1st mx. (zoea) ×63. (P) 2nd mx. (zoea) ×63. (Q) abdomen (zoea ×14.

well developed. Enp. has 4 joints, exp. 2. Exp. has 8 swimming hairs. Cheliped fairly well developed, but other 4 feet only incompletely segmented. Abdomen composed of 6 somites and telson. Lateral knobs on 4th and 5th somites. Lateral ends of 5th and 6th somites very prominent, but those of 3rd and 4th somites only slightly projected. Single bands of stiff hairs on 1st and 3rd to 5th somites, 2 bands on 2nd somite. Telson G-type, trapezoidal, with long spine and small denticle on lateral corner. Lower margin with 14 long plumose hairs close together. Uropod of last somite has 2 terminal hairs.

Megalopa. Carapace longer in megalopa than in zoea, narrowing anteriorly. Armatures of carapace similar to those of zoea. Lateral horns markedly elongated (though broken in this specimen). Rostrum and median horn show no noticeable change in shape. Small tubercle on lateral side behind eye. Cheliped and 4 legs markedly long and slender. 1st ant. 2-branched and long. Basal part 3-jointed, enp. 2-jointed, exp. 5-jointed. Sensory tubes on distal edge of 2nd to 4th joints and basal part of 5th joint. 5th joint very slender, ends in 2 unequal hairs. 2nd ant. single, slender, separable into 3 parts. Basal part has 3 thick joints, middle part 5 joints. 4th joint very small, but other 4 long, slender. Distal part has 4 joints. Ring of 4 long stiff hairs on distal edge of 6th, 8th, 10th, and 11th joints. Distal joint has 2 terminal hairs. Mandible with palp of single joint, its chewing surface roughly tuberculed, its outer margin serrated. Enpds. of both mxls. markedly reduced. Enp. of 2nd mx. ends in short hair, has 3 long smooth hairs along outer side, 1 on inner. Epipodite (Epip.) of 1st mxp. flattened, triangular. Enp. hammer-shaped process, 2-jointed. Enp. of 2nd mxp. has 5 joints, exp. 2. The epip., which is long, flattened, is a peduncular process, with serrations all around it. Enp. of 3rd mxp. has 5 joints, basal 1st joint provided with toothed ridge along its inner side. Epip. resembles that of 2nd mxp. Propodite (prp.) of 2nd and 3rd legs widened distally. Dactylopodite (dactyl.) of last leg short, slender, bearing 2 terminal and 1 lateral curly feelers. Abdomen composed of 6 somites and telson. All somites smooth. Uropod of last somite has 2 terminal hairs. Lateral side of last somite prominent ventrally.

4. *Dorippe granulata* DE HAAN. 1st zoea. Fig. 6.

Characters: Dorsum and rostrum present, 2nd ant. A_3-type, telson C-type, no stable brown chromatophores present in abdomen and in mxpds., hair formula 4–0, 4, 2–1–0.

Dorsum 3.10 mm, rostrum 4.50 mm, perpendicular distance between their tips 8.44 mm, carapace 0.84 mm long; abdomen 1.88 mm long, 0.12 mm wide; telson 0.74 mm.

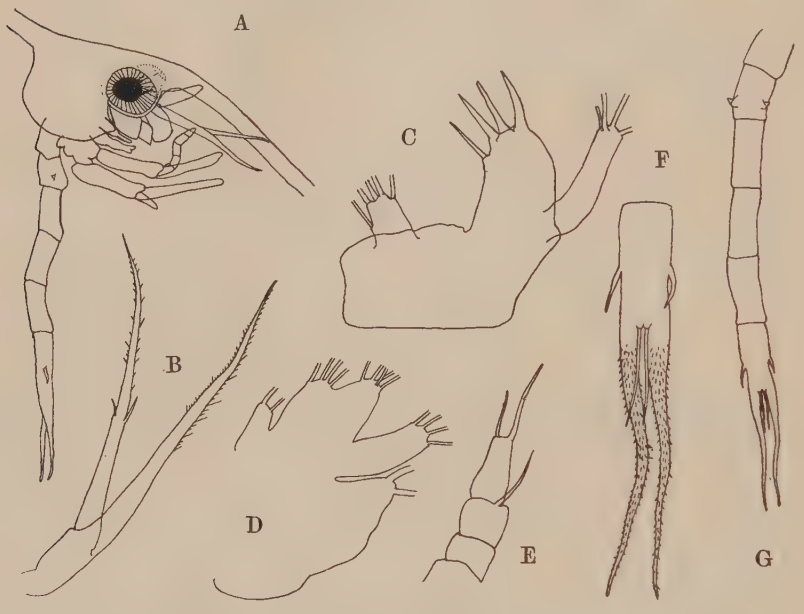


Fig. 6. *Dorippe granulata* D. H. 1st zoea.
(A) lateral view ×21. (B) 2nd ant. ×87. (C) 1st mx. ×177. (D) 2nd mx. ×177. (E) enp. of 2nd mxp. ×177. (F) telson ×61. (G) abdomen ×35.

Larva very large already at 1st stage; rostrum, dorsum, and abdomen markedly long and slender. 1st ant. usual form, slender. 2nd ant. A_3-type. Peduncle and exp. nearly same length, slender, long, armed with fine teeth on both sides. Exp. bears 2 large spinules on middle part. Enp. of 1st mx. of single joint with 4 long hairs on tip. Coxopodite of 1st mx. far apart from other 2. Only the basipodite of 2nd mx. bifurcated, other 2 single. Coxopodite with 2 hairs, enp. with 4. Basipodite has 5 hairs on inner lobe, 4 on outer. Scaphognathite with 2 hairs near its upper corner. Enp. of 2nd mxp. has 3 joints; 1st joint hairless, 2nd 1 on its distal edge, 3rd 2 on its tip. Small rudiments of 3rd mxp. and 5 pairs of pereiopods present behind 2nd mxp. Abdomen composed of 5 somites and telson. All somites long, similar in shape. Lateral knobs only on 2nd somite. Telson C-type. Telson-fork covered all over with fine serrations. Large spine on each

side of telson. Pair of inner spines thick, nearly 1/3 of telson-fork.

5. *Dorippe* sp. A 2nd zoea. Fig. 7.

Characters: Dorsum and rostrum present, 2nd ant. A_3-type, telson C-type, no brown chromatophore present, hair formula 4–0, 4, 3–1–0.

Many zoeas from the 2nd to the last stage were collected among sardine larvae off Watanoha, Miyagi Pref. in August, 1935.

At 2nd stage, dorsum 6.55 mm, rostrum 5.40 mm, perpendicular distance between their tips 13.2 mm, carapace 1.25 mm, abdomen 3.03 mm long, 0.14 mm wide, telson 1.08 mm.

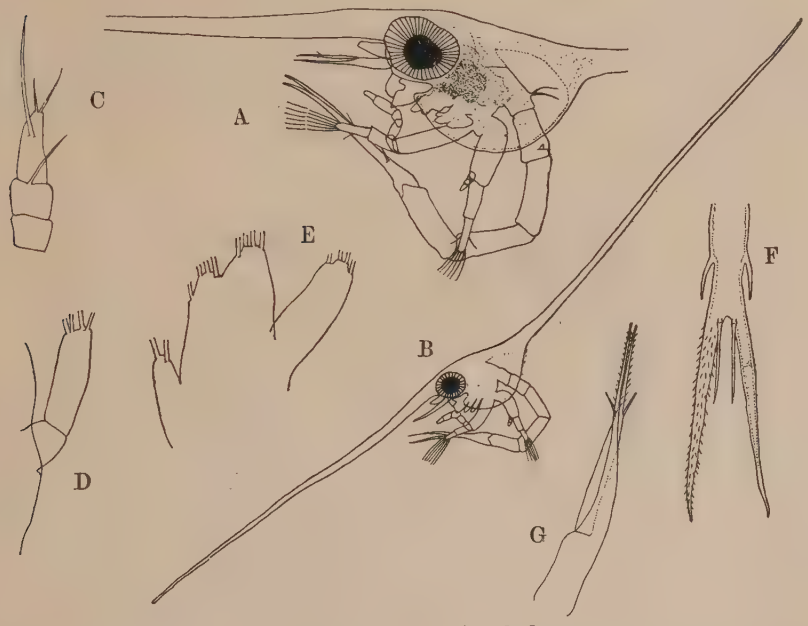


Fig. 7. *Dorippe* sp. A. 2nd zoea.
(A) lateral view × 21. (B) total view × 9. (C) enp. of 2nd mxp. × 180. (D) enp. of 1st mx. × 180. (E) 2nd mx. × 180. (F) telson × 39. (G) 2nd ant. × 61.

Dorsum and rostrum unusually long. Carapace oval laterally. Its lower margin coarsely serrated. 1st and 2nd ants. long, slender, resembling that of *Dorippe granulata*. Enp. of 2nd ant. not yet in appearance at 2nd stage. Enp. of 1st mx. has 2 joints, only distal 2nd joint tipped with 4 hairs. 2nd mx. exactly the same as that of *Dor. gran.* Scaphognathite has 4 long plumose hairs near upper corner, 2 on lower lateral margin. Exp. of mxpds. 2 jointed, with 6 swimming,

2 accessory hairs. Enp. of 2nd mxp. has 3 joints; 1st joint hairless, 2nd 1 on its distal edge, 3rd 3 on tip. 3rd mxp. and 5 pairs of pereiopods not yet in eviednce at 2nd stage. Abdomen composed of 5 somites and telson, as 6th somite not yet separated from telson. Lateral knobs on 2nd somite, 2 dorsal hairs on 1st. Telson resembles much that of *Dor. gran.*, although more densely chitinized than that of latter.

6. *Dorippe* sp. B. Fig. 8. Last zoea.

Characters: Similar in every respect to the preceding, except the hair formula 4–0, 4, 4–1–0.

Dorsum and rostrum very prominent. Both antennae and maxillae similar to those of *Dor. gran.* and *Dor.* sp. A. Enp. of 2nd mxp. has 3 joints, mode of serration here expressed by 4–1–0, thus differing from other 2 larvae. Abdomen very long, slender. Lateral knob wholly absent. Telson also resembles that of *Dor. gran.*

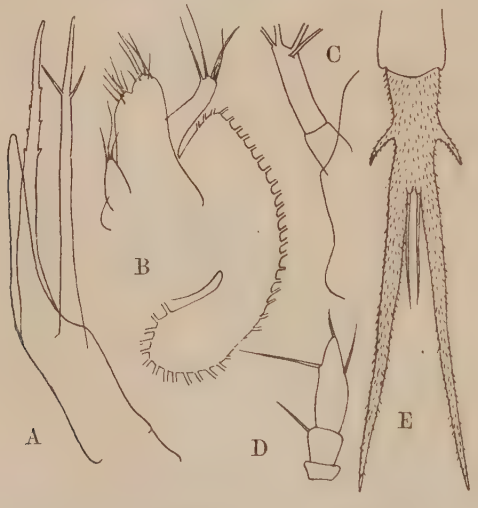


Fig. 8. *Dorippe* sp. B. Last zoea.
(A) 2nd ant. × 43. (B) 2nd mx. × 61. (C) 1st mx. × 72. (D) enp. of 2nd mxp. × 72. (E) telson × 26.

7. *Calappa lophos* (Herbst) 1st zoea. Fig. 9.

Characters: All kinds of carapacial spines present, 2nd ant. B_2-type, telson A_2-type, no stable brown chromatophores present, hair formula 6–0, 2–5 (7), 4–1–1.

Zoea medium size. Dorsum 0.45 mm, rostrum 0.11 mm, perpendicular distance between tips 1.18 mm; carapace 0.50 mm long, 0.36 mm

wide, lateral spine 0.18 mm; abdomen 1.05 mm long, 0.12 mm wide, telson 0.37 mm.

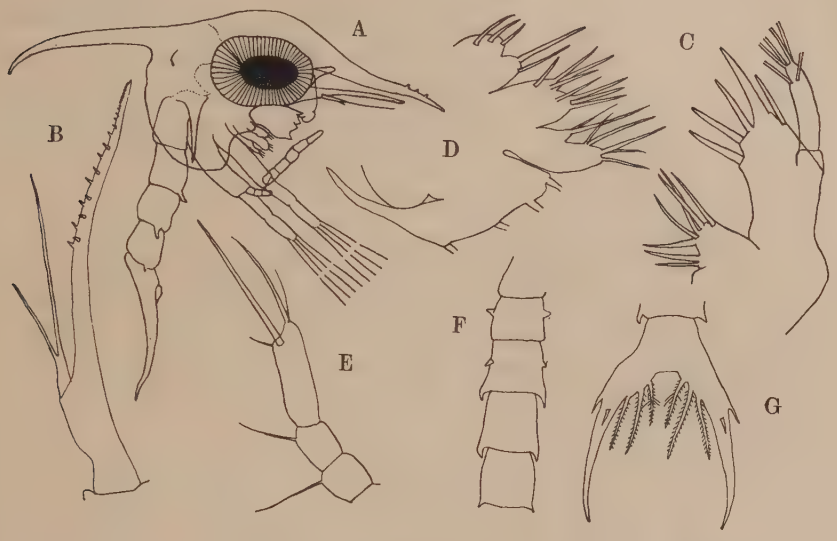


Fig. 9. *Calappa lophos* (HERBST). 1st zoea.
(A) lateral view × 43. (B) 2nd ant. × 233. (C) 1st mx. × 287. (D) 2nd mx. × 287. (E) enp. of 2nd mxp. × 377. (F) abdomen × 61. (G) telson × 72.

Dorsum and rostrum thick, fairly long, pointed. Rostrum has denticles on dorsal side of distal part. Lateral spine rather slender, pointed. Eye large. 1st ant. usual form. 2nd ant. B_2-type; peduncle thick at base, pointed at end, armed with fine teeth at distal half. Exp. small, ending in very long stiff hair, with a hair on basal part. Mandible has large teeth on chewing surface. Enp. of 1st mx. has 2 joints; 1st joint hairless, but 2nd has 4 terminal hairs and 1 lateral. All podites of 2nd mx. slightly bifurcated. Outer lobe of enp. smaller than inner; former with 2 stiff hairs, latter with 5. Scaphognathite rather small, tapering, with 4 lateral plumose hair. Enp. of 2nd mxp. has 3 joints; both 1st and 2nd joints with 1 hair each, 3rd with 4 terminal hairs. 3rd mxp. and 5 pairs of pereiopods not yet in evidence. Abdomen composed of 5 somites and telson. Lateral knobs on 2nd and 3rd somites. Lateral ends. of 3rd to 5th somites more or less projected. All abdominal somites of same size. Teslon A_2-type, with 1 lateral and 1 dorsal denticle on middle part of telson-fork; last named long and slender. Lengths of 3 pairs inner spines unequal, 2nd pair being

longest and 3rd shortest. 3rd pair has 2 long hairs among the short ones on inner side and 1 long one on outer side. Middle depression shallow but wide.

The zoea of Calappidae is easily distinguished from other larvae of Doromiidea and Oxystomata. The Calappid zoea greatly resembles the usual brachyuran zoea, except that no stable brown chromatophore is present. Of the Oxystomata, the Calappid zoea alone has the B-type of 2nd ant. Its phylogenic position may be the highest among the Oxystomata.

8. *Ebalia longipedata* Ortmann. 1st zoea. Fig. 10.

Characters: Only short lateral spines present, 2nd ant. D-type, telson E-type, hair formula 4, 3, 3.

Lateral spine 0.05 mm, carapace 0.51 mm; abdomen 0.78 mm long, 0.14 mm wide, telson 0.18 mm.

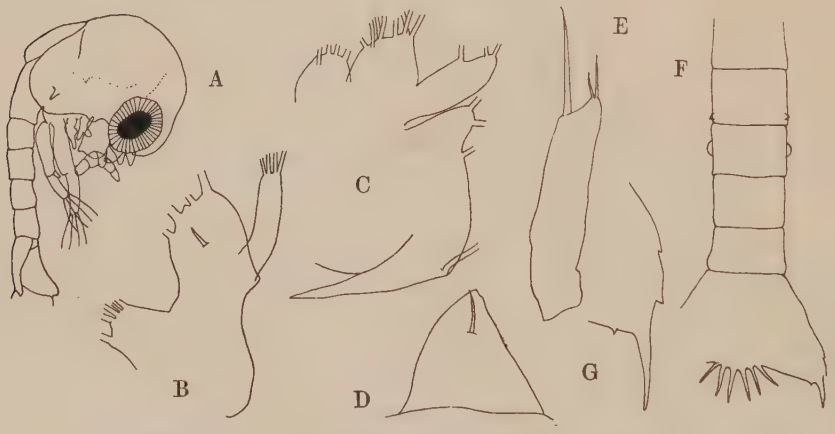


Fig. 10. *Ebalia longipedata* Ortmann. 1st zoea.
(A) lateral view × 39. (B) 1st mx. × 233. (C) 2nd mx. × 233. (D) 2nd ant.. × 233. (E) enp. of 2nd mxp. × 467. (F) abdomen × 72. (G) lateral corner of telson × 233.

Lateral spines present on postero-lateral part of carapace. 1st ant. usual form, 2nd ant. much reduced, D-type, with a short hair near its side. Enp. of 1st mx. only of singel joint, tipped with 4 hairs. Enp. of 2nd mx. also single with 2 terminal hairs and 1 lateral. Enp. of 2nd mxp. also of single joint with 1 long and stout hair and 2 short ones on tip. Lateral knobs on 2nd and 3rd somites; that on 2nd somite usually absent in Leucosiid zoea, whereas in this zoea, they are very small and triangular. Those on 3rd somite very large and semicircular.

In other respects all abdominal somites similar other. Telson E-type, almost semicircular, with large tooth on lateral corner, also 2 small denticles above and 1 below it. 3 pairs of inner spines closely arranged on middle part of lower margin.

9. *Pleistacantha sancti-johannis* MIERS. Prezoea. Fig. 11.

Characters: Only lateral spines absent, 2nd ant. A_3-type, telson A_3-type, hair formula 6–1, 5, 4–1–0.

Larva, being in prezoeal stage, difficult to measure, but rather large compared with those of the Inachidae. Abdomen about 1.43 mm long. Dorsum long, pointed, bends backwards. Rostrum rather straight. 2nd ant. A_3-type. Peduncle and exp. almost same length; both smooth, except 2 spinules on middle part of exp. Enp. on 2nd ant. not yet observable at this pre-zoeal stage, but small rudiments of 3rd mxp. and pereiopods present. Enp. of 1st mx. 2-articulate. 1st joint has 1 hair on distal edge, 2nd 6 on tip. Enp. of 2nd mx. single, tipped with 6 terminal hairs. Enp. of 2nd mxp. has 3 joints; 1st joint hairless, 2nd 1 hair, 3rd 4. Lateral knobs only on 2nd somite; lateral ends of 3rd to 5th somites slightly prominent. Telson A_3-type. 3 pairs

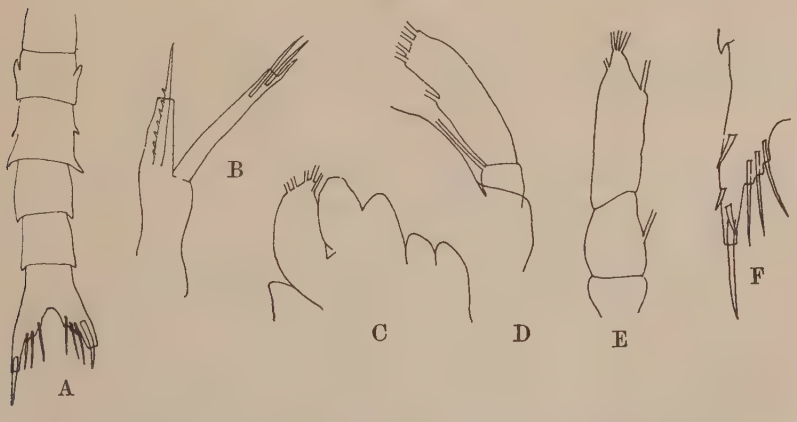


Fig. 11. *Pleistacantha sancti-johannis* MIERS. Prezoea.
(A) abdomen × 39. (B) 2nd ant. × 83. (C) 2nd mx. × 233. (D) enp. of 1st mx. × 233. (E) enp. of 2nd mxp. × 233. (F) telson-fork × 72.

of inner spines arranged so closely that middle depression cannot be recoginzed. Telson-fork thick at base, pointed at end, covered with longitudinal rows of fine serrations.

10. *Paratymolus pubescens* MIERS. 1st zoea. Fig. 12.

Characters: Dorsum and rostrum present, 2nd ant. B_2-type, mxpdal chrom. absent, 1 large longitudinal chrom. involves the 1st and 2nd somites and one also with 5th and telson (probably with 5th and 6th somites in later stage), and a pair in 3rd and 4th somites each, telson A_1-type, hair formula 6–1, 3–5 (8), 2–0–0.

Dorsum 0.62 mm, rostrum 0.39 mm, perpendicular distance between tips 1.30 mm; carapace 0.42 mm long, 0.39 mm wide; abdomen 0.83 mm long, 0.13 mm wide, telson 0.27 mm.

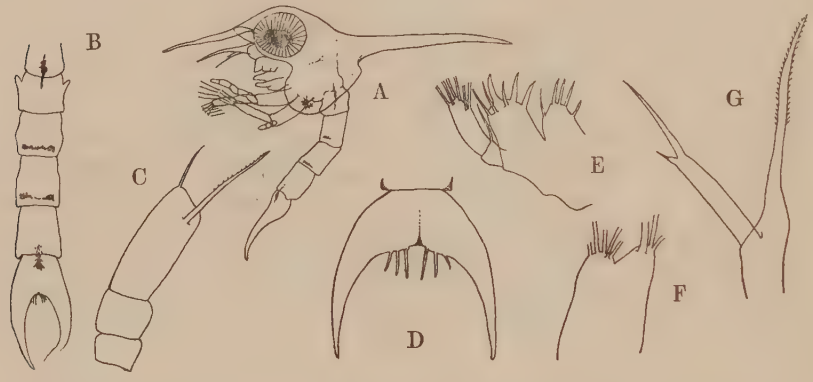


Fig. 12. *Paratymolus pubescens* MIERS 1st zoea.
(A) lateral view × 39. (B) abdomen × 61 mm. (C) 1st mx. × 287. (D) enp. of 2nd mxp. × 420. (E) telson × 83. (F) 1st mx. × 180. (G) enp. of 2nd mx. × 420. (H) 2nd ant. × 180.

Zoea rather small at 1st stage. Dorsum thick, long; rostrum rather slender. Both projecting almost straight. Large carapacial chrom. present in lower part of carapace. 1st ant. usual form, long. 2nd ant. B_2-type. Peduncle slender, toothed on both sides at distal half. Exp. only slightly shorter than peduncle with tooth on middle part, where it becomes abruptly slender to end. Mandible densely pigmented. Enp. of 1st mx. has 2 joints, 1st joint has 1 hair on distal edge, 2nd tipped with 4 hairs in addition to 2 lateral hairs. All podites of 2nd mx. moderately bifurcated. Enp. provided with 3 hairs on inner lobe with 5 on outer. Enp. of 2nd mxp. has 3 joints, its distal joint bearing 2 stiff hairs. 3rd mxp. and 5 pairs of pereiopods not yet developed. Abdomen composed of 5 somites and telson. Lateral knobs present only on 2nd somite. Telson crescent-shaped. Telson-fork thick at base, pointed at end. 3 pairs of inner spines of different lengths, 1st

outer pair shortest, 3rd inner longest. Middle depression thickly chitinized.

11. *Achaeus* sp. A. 1st zoea. Fig. 13.

Characters: Only dorsum present, 2nd ant. A_3-type, telson A_1-type, hair formula 4–0, 4, 4–0–0.

Dorsum 0.59 mm, carapace 0.64 mm, abdomen 1.50 mm long, 0.19 mm wide, telson 0.54 mm.

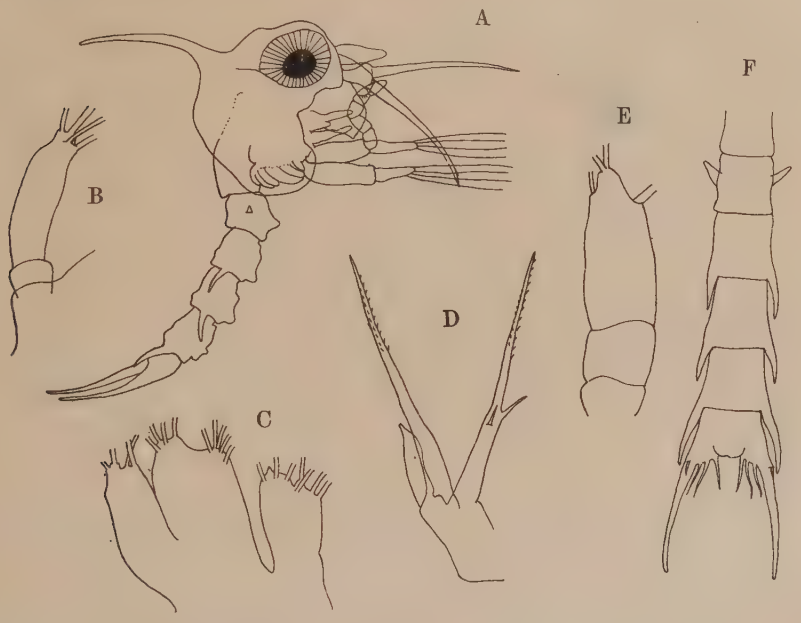


Fig. 13. *Achaeus* sp. A. 1st zoea.
(A) lateral view ×33. (B) enp. of 1st mx. ×233. (C) 2nd mx. ×233. (D) 2nd ant. ×72. (E) enp. of 2nd mxp. ×233. (E) abdomen ×41.

Dorsum long, pointed, curved posteriorly. 1st ant. usual form; 2nd ant. A_3-type, very large. Peduncle and exp. almost same length, both closely toothed on two sides at their distal halves. Exp. has in addition 2 spinules on middle part. Enp. already ⅓ of peduncle at this 1st stage. Enp. of 1st mx. 2-articulate, mode of serration here expressed by 4–0. Enp. of 2nd mx. single, but other podites bifurcated. Enp. tipped with 4 long hairs, that of 2nd mxp. has 3 joints, distal 3rd joint provided with 4 hairs, but others with none. Rudiments of 3rd mxp. and pereiopods large. Lateral knobs present only on 2nd

abdominal somites; lateral ends of 3rd to 5th somites very prominent. Telson A_1-type, with denticle on dorsal side of telson-fork, which long, slender. Middle depression wide but shallow. 3 pairs on inner spines short.

13. *Achaeus* sp. B. 1st zoea. Fig. 14.

Characters: Similar to *Achaeus* sp. A., except hair formula 3–0, 4, 4–0–0.

Dorsum 0.52 mm, carapace 0.66 mm; abdomen 1.47 mm long, 0.19 mm wide, telson 0.47 mm.

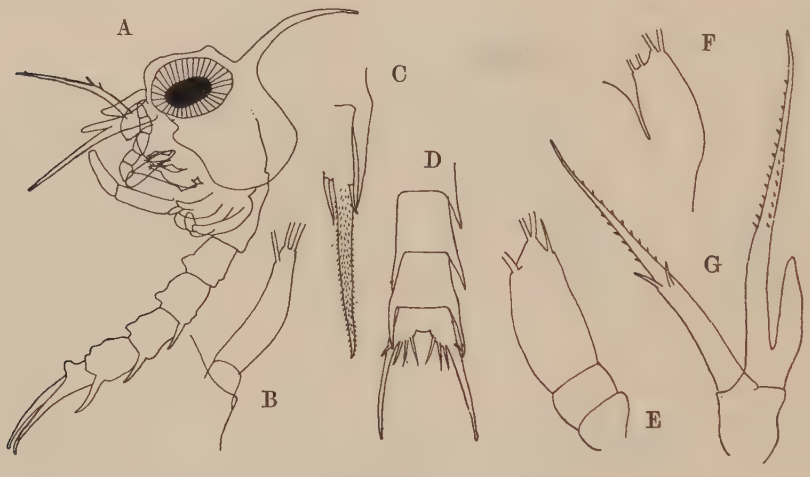


Fig. 14. *Achaeus* sp. B. 1st zoea.
(A) lateral view ×33. (B) enp. of 1st mx. ×233. (C) telson-fork ×72. (D) abdomen ×39. (E) enp. of 2nd mxp. ×233. (F) enp. of 2nd mx. ×233. (G) 2nd ant. ×83.

Dorsum slender, pointed, curved backwards. Carapace so small that extremities remain uncovered. 1st and 2nd ants. similar to those of *Achaeus* sp. A. Enp. of 1st mx. has also 2 joints, but its distal joints bears only 3 hairs, being less by 1 than those of *Achaeus* sp. A. 2nd mx., mxpds., abdomen also nearly similar to those of *Achaeus* sp. A. Telson-fork more slender, attaining to nearly ¾ the total length of the telson, being covered all over with fine hairs.

13. *Huenia proteus* DE HAAN. 1st zoea. Fig. 15.

Characters: Dorsum and rostrum present, 2nd ant. A_3-type, telson A_1-type, primary chrom. present in 2nd mxp. and 1 abdominal chrom. involving 1st and 2nd somites, hair formula 5–0, 4, 4–1–0.

Dorsum 0.18 mm, rostrum 0.10 mm, perpendicular distance be-

tween tips 0.77 mm, carapace 0.66 mm, abdomen 1.00 mm long, 0.14 mm wide, telson 0.43 mm.

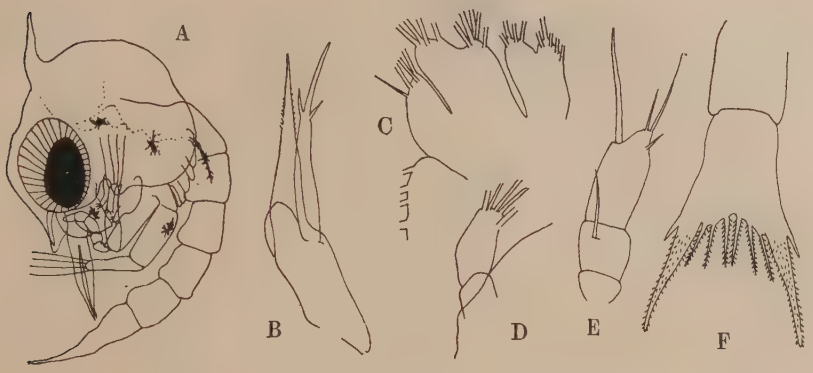


Fig. 15. *Huenia proteus* D. HAAN. 1st zoea.
(A) lateral view × 40. (B) 2nd ant. × 83. (C) 2nd mx. × 233. (D) enp. of 1st mx. × 233. (E) enp. of 2nd mxp. × 233. (F) telson × 72.

Zoea rather small. Both dorsum and rostrum short, pointed. Carapace nearly spherical. 2nd ant. A_3-type. Both peduncle and exp. long, thick. Exp. bears 2 spinules on middle part. Enp. attains nearly ¼ of peduncle length. Enp. of 1st mx. has 2 joints, mode of serration here expressed by 5–0. Enp. of 2nd mx. similar to that of *Achaeus*. Enp. of 2nd mxp. has 3 joints. Distal 3rd joint with 4 hairs, 2nd with 1, but 1st with none. Small rudiments of 3rd mxp. and pereiopods observed. Primary chrom. present only in protopodite of 2nd mxp.

Lateral knobs only on 2nd abdominal somite. Lateral ends of all somites rather rounded. Telson A_1-type, with denticle laterally near base of telson-fork. Telson-fork thick at base, pointed at end, being covered all over with fine hairs. As 3 pairs of inner hairs closely arranged, middle depression hardly recognizable.

14. *Naxia hystrix* MIERS. 1st zoea. Fig. 16.

Characters: Dorsum and rostrum present, 2nd ant. A_3-type, telson A_1-type, hair formula 6–1, 5, 4–1–0.

Dorsum 0.48 mm, rostrum 0.12 mm, perpendicular distance between tips 0.82 mm, carapace 0.55 mm, abdomen 1.07 mm long, 0.17 mm wide, telson 0.38 mm.

Dorsum pointed, curved backwards. Rostrum short, straight. 2nd ant. A_3-type. Both peduncle and exp. thick, smooth, except 2 spinules

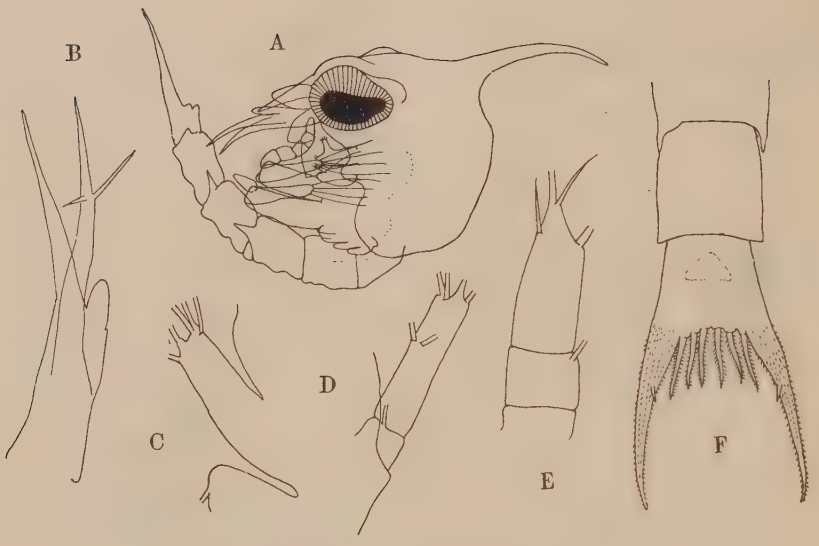


Fig. 16. *Naxia hystrix* Miers. 1st zoea.
(A) lateral view × 33. (B) 2nd ant. × 83. (C) enp. of 2nd mx. × 233. (D) enp. of 1st mx. × 233. (E) enp. of 2nd mxp. × 233. (F) telson × 61.

on middle part of exp. Enp. very small, that of 1st mx. 2-articulate, mode of serration here expressed by 6–1. Enp. of 2nd mx. single, tipped with 5 hairs, that of 2nd mxp. similar to that of *Huenia proteus*. Small rudiments of 3rd mxp. and pereiopods observed.

Lateral knobs only on 2nd abdominal somite, lateral ends of 3rd to 5th somites slightly projected. Telson A_1-type, denticle dorsally on middle part of telson-fork, which is long, pointed, covered all over with fine hairs. 3 pairs of inner hairs so closely arranged that middle depression hardly recognizable.

15. *Chionecetes opilio* Fabricius. Prezoea. Fig. 17.

Characters: All carapacial spines present, 2nd ant. B_6-type, telson A_2-type, hair formula 5–1, 2–3 (5), 5–?–?.

The writer, in his previous paper (Aikawa, 1), reported that sometimes lateral spines may or may not be present, which however was an error. All extremities, including the carapacial spines, are usually not fully developed in the larva, seeing that the larva is obtained as a rule only at the prezoeal stage. There really occur 3 kinds of carapacial spines.

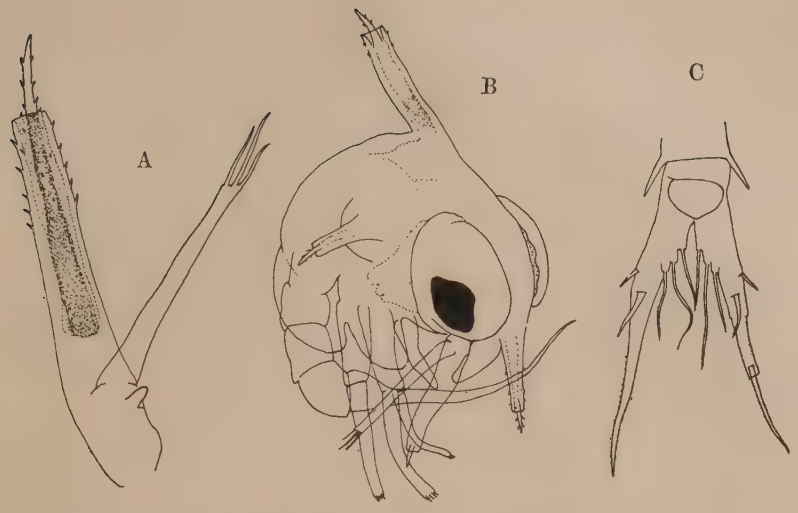


Fig. 17. *Chionecetes opilio* (Fabricius). Prezoea.
(A) 2nd ant. ×72. (B) lateral view ×40. (C) telson ×39.

K. Stephensen (1935) described the later zoeal stage of *Chionecetes opilio,* which he obtained among plankton samples collected near Greenland, but it differs in important respects from that obtained by the present writer from berried crabs.

Carapacial spines coarsely toothed, although smooth in zoea described by Stephensen. 2nd ant. B_6-type. Peduncle long, with small denticles all over it. Exp. attains to only ⅓ of peduncle, ending in 3 soft hairs. Enp. not yet in evidence at this prezoeal stage. 2nd ant. in Stephensen's zoea differs greatly from that just mentioned. Exp. nearly ⅔ of peduncle, ending in 2 unequal hairs. It is exactly of B_4-type.

Enp. of 1st mx. 2-jointed, mode of serration here expressed by 5–1. Enp. of 2nd mx. biramous, mode of serration here 2–3(5). Enp. of 2nd mxp. has 3 joints; distal 3rd joint with 5 hairs, but serration on 1st and 2nd joints not ascertainable at prezoeal stage. Rudiments of 3rd mxp. and pereiopods already observable. Lateral knobs present only on 2nd somite, lateral ends of 3rd to 5th somites prominent. Telson A_2-type, since it has 2 denticles dorsally on middle part of telson-fork. Middle depression fairly deep. Whereas in Stephensen's zoea, enp. of 2nd mxp. has 5 joints notwithstanding that all zoeas of Inachidae and Majidae have enp. of 1 or 3 joints. Lateral knobs present on both

2nd and 3rd abdominal somites, although occurring only on 2nd somite in the zoeas of both Inachidae and Majidae. Telson also A_2-type; only 1 spinule present dorsally on middle part of telson-fork, but the other, attaining to nearly same length as telson-fork, present laterally near base of telson-fork. Therefore telson resembles that of *Erimacrus einsenbeckii* (Fig. 23, G), which has enp. of 3 joints in 2nd mxp. Thus the differences in their detailed structures, such as the mode of serration, type of 2nd ant., and abdominal structure, are many. The zoea described by STEPHENSEN may not belong to *Chionecetes opilio*. At the same time the genus or family of this zoea cannot be determined owing to the fact that Grapsizoeas provided with B-type of 2nd ant. and A-type of telson are found in several families.

16. *Tiarinia cornigera* (M.-EDWARDS) 1st zoea. Fig. 18.

Characters: Rostrum and dorsum present, 2nd ant. A_3-type, telson A_3-type, hair formula 6–1, 3–5 (8), 6–1–1.

Dorsum 0.29 mm, rostrum 0.12 mm, perpendicular distance between tips 0.82 mm, carapace 0.55 mm; abdomen 1.07 mm long, 0.17 mm wide, telson 0.38 mm.

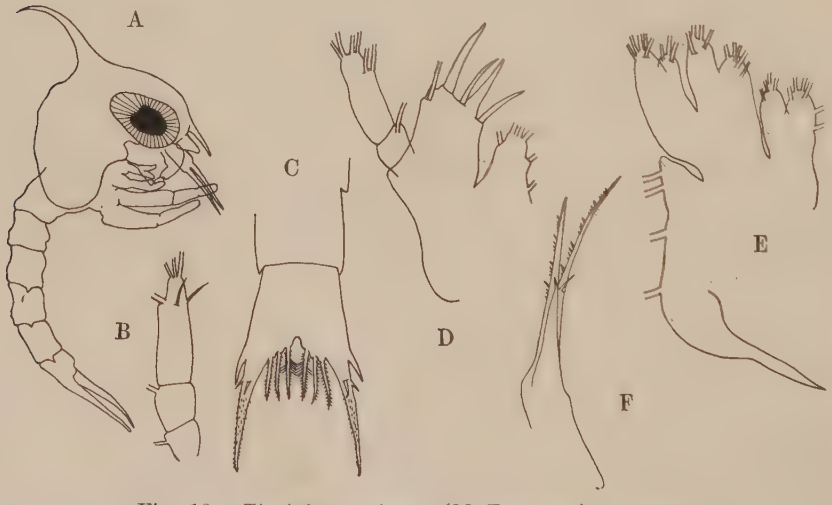


Fig. 18. *Tiarinia cornigera* (M.-EDWARDS) 1st zoea.
(A) lateral view ×37. (B) enp. of 2nd mxp. ×233. (C) telson ×72.
(D) 1st mx. ×233. (E) 2nd mx. ×233. (F) 2nd ant. ×121.

This zoea differs from those of the Majidae in several respects. Rostrum short, pointed. Dorsum curves markedly backwards. Eye

depressed. 2nd ant. A_3-type, longer than rostrum. Exp. also longer than peduncle, has 2 spinules on middle part. Both peduncle and exp. have small teeth at distal half. Enp. of 1st mx. very small, mode of serration 6–1. Enp. of 2nd mx. biramous, mode of serration 3–5 (8). Enp. of 2nd mxp. has 3 joints, both 1st and 2nd joints with 1 hair each, 3rd with 6 on tip, although in zoeas of both Inachidae and Majidae 1st joint hairless.

Lateral knobs only on 2nd somite, lateral ends of 3rd to 5th somites slightly projected. Telson A_3-type, 2 lateral and 1 dorsal denticles on telson-fork, which is slender and covered all over with fine hairs. 3 pairs of inner spines of same length, inner 3rd pair has 6 long hairs among short ones on inner side, 2 or 3 ones on outer side. Middle depression narrow but fairly deep.

17. *Lambrus validus* DE HAAN. 1st zoea. Fig. 19.

Characters: All kinds of carapacial spines present, 2nd ant. B_4-type, telson A_1-type, no mxpdal. chrom. present, hair formula 6–1, 2–5 (7), 3–1–1.

Dorsum 0.31 mm. rostrum 0.30 mm. perpendicular distance between tips 0.99 mm. lateral spine 0.13 mm; carapace 0.49 mm. long, 0.29 mm wide; abdomen 0.65 mm long, 0.14 mm wide, telson 0.21 mm.

Dorsum thick, pointed, curved backwards. Rostrum shorter than

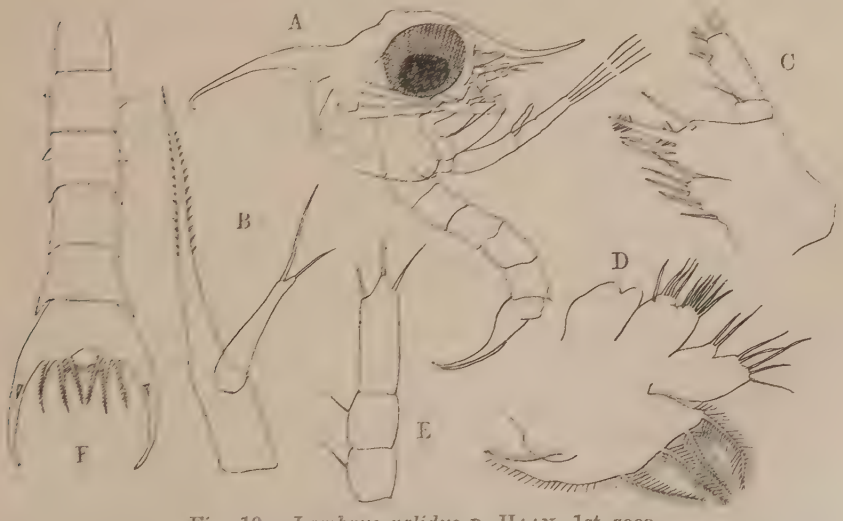


Fig. 19. *Lambrus validus* D. HAAN. 1st zoea.
(A) lateral view × 61. (B) 2nd ant. × 287. (C) 1st mx. × 287. (D) 2nd mx. × 287. (E) enp. of 2nd mxp. × 420. (F) abdomen × 87.

dorsum, curves concavely. Lateral spine short, curved. Fine hair between dorsum and lateral spine, small tubercle on frontal region. 1st ant. usual form, few sensory hairs on tip. 2nd ant. B_4-type, shorter than rostrum. Peduncle straight, pointed, armed with fine teeth along both sides of distal half. Exp. nearly half the length of peduncle, tipped with 2 unequal stiff hairs. 1st mx. has 2-jointed enp., 1st joint bears 1 hair on distal edge, 2nd with 4 long hairs on tip, with 2 a little below them. All podites of 2nd mx. fairly bifurcated. 2 lobes of enp. unequal in size, smaller outer lobe with 2 hairs, larger inner with 5. Scaphognathite medium size, 4 long plumose hairs laterally, ending in pointed horn. Exp. of mxp. slightly segmented at this 1st stage. Enp. of 2nd mxp. has 3 joints, both 1st and 2nd joints with 1 hair each, 3rd with 3 on tip. Abdomen of 5 somites and telson. Lateral knobs present on 2nd and 3rd somites, fairly large. Lateral ends of 3rd and 4th somites somewhat prominent. Telson A_1-type, dorsal denticle on middle part of telson fork. 3 pairs of inner spines of same length, inner 3rd pair has 4 long hairs among short ones on inner side, 1 long hair on outer side. Middle depression wide but shallow. Telson-forks converge towards their ends.

18. *Charybdis 6-dentata* Herbst. 1st zoea. Fig. 20.

Characters: All kinds of carapacial spines present, 2nd ant. B_2-type, telson A_2-type, secondary chrom. present in 1st mxp, abdominal ones in all somites except telson, hair formula 6–1, 2–4 (6), 4–1–1.

Dorsum 0.44 mm, rostrum 0.35 mm, perpendicular distance between tips 1.16 mm, lateral spine 0.14 mm, carapace 0.48 mm; abdomen 0.75 mm long, 0.10 mm wide, telson 0.34 mm.

Larva rather small. Dorsum curves backwards, hooked at end. Rostrum rather straight. Lateral spine short, thick at base, pointed at end. 2nd ant. B_2-type. Peduncle same length as rostrum, armed with fine denticles along both sides in distal half. Exp. short, ends in 2 unequal hairs. Enp. of 1st mx. 2-articulate, mode of serration here expressed by 6–1. All podites of 2nd mx. bifurcated, although enp. only slightly, its inner lobe has 4 hairs, outer only 2. 1st mxp. has secondary chrom. in its protopodite. Enp. of 2nd mxp. has 3 joints. Both 1st and 2nd somites bear 1 hair each, 3rd 4 on tip. Rudiments of 3rd mxp. and 5 pairs of pereiopods present at this 1st stage, as seen in 1st zoea of both Inachidae and Majidae. Lateral knobs present only on 2nd somite. Abdomen slender, lateral ends of both 3rd and 4th

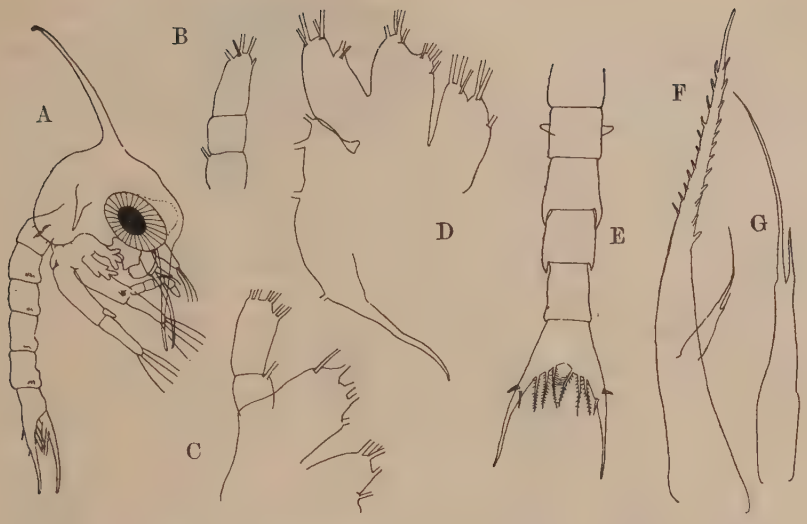


Fig. 20. *Charybdis 6-dentata* Herbst. 1st zoea.
(A) lateral view × 39. (B) enp. of 2nd mxp. × 233. (C) 1st mx. × 233. (D) 2nd mx. × 233. (E) abdomen × 72. (F) 2nd ant. × 233. (G) enp. of 2nd ant. × 467.

somites slightly prominent. Telson-forks diverge, very slender. 2 outer denticles present dorsally on telson-fork. Middle depression shallow. 3 pairs of inner spines of same length, inner 3rd pair has 6 long hairs among short ones on inner side.

19. *Charybdis bimaculata* Miers. 4th zoea to megalopa. Figs. 21, 22.

Characters: All kinds of carapacial spines present, 2nd ant. B_2-type, telson A_2-type, hair formula 6–1, 2–4 (6), 5–1–1.

At a station (123°–48′ E.L., 31°–00′ N.L.) in the Chinese Eastern Sea, later zoeas, megalops, and young crabs were collected during September and October on board M.S. "Hizyun-maru". These larvae, which probably formed a swarm near the bottom, were found to belong to *Charybdis bimaculata* Miers, resemble in zoeal stage that of *Charybdis 6-dentata* described above.

Rostrum 0.67 mm, dorsum broken, carapace 1.02 mm, lateral spine 0.13 mm; abdomen 1.73 mm long, 0.29 mm wide, telson 0.52 mm.

Rostrum nearly straight, pointed, but dorsum probably curves backwards. Lateral spine short. 2nd ant. B_2-type. Exp. longer than ½ of peduncle, becomes abruptly slender at ⅓ of distal part. Peduncle provided with fine teeth at ⅓ of distal part. Enp. only ⅓ of peduncle

Fig. 21. *Charybdis bimaculata* MIERS. Later zoeas and megalopa.
(A) lateral view (V zoea) ×26. (B) dorsal view (I megalopa) ×17. (C) dorsal view (II megal.) ×13. (D) dorsal view (young crab) ×13. (E) frontal margin (crab) ×13. (F) dorsal view (crab) ×13. (G) 2nd ant. (I megal.) ×42. (H) 2nd ant. (young crab) ×21. (I) 2nd ant. (V zoea) ×72. (J) abdomen (IV zoea) ×41. (K) enp. of 2nd ant. (V zoea) ×233. (L) abdomen (V zoea) ×26. (M) abdomen (I megal.) ×40.

at this last stage. Rudiments of 3rd mxp. and pereiopods also very small. Enp. of 1st mx. similar to that of *Chary. 6-dent.* Enp. of 2nd mx. of only slightly bifurcated, mode of serration here also similar to *Chary. 6-dent.* Enp. of 2nd mxp. has 3 joints; both 1st and 2nd joints provided with 1 hair each, 3rd with 5. Abdomen composed of 6 somites and telson. Lateral knobs present on both 2nd and 3rd somites, lateral ends of 3rd to 5th somites slightly projected. Telson A_2-type, 1 denticle laterally near base of telson-fork, 1 dorsally on middle part. 3 pairs of inner spines of same length, 3 or 4 accessory hairs present.

Megalopa. Megalopa changes to young crab after passing through 2 stages as assumed from the occurrence of 2 modes in the width of carapace and the length of the abdomen.

Stage	Carapace		Abdomen	
	length mm	width mm	length mm	width mm
I	2.16	1.13	1.27	0.42
II	3.57	1.17	2.04	0.73

Carapace usually quadrate. Rostrum long, slender. No other spine present on carapace. Viewed dorsally, 1st ant. covered under carapace and eye-stalk. 1st ant. 2-branched. Basal portion 3-articulate, triangular at young crab stage, although undergoes no change. Exp. single at I megalopa stage, 2-articulate at II megalopa stage and in young crab. 2nd ant. simpler in structure in megalopa stage than in zoea, and consists of 3 parts. Terminal part only 2-articulate, articulation does not increase in young crab stage. Middle part 5-articulate at I megalopa, but 7-articulate in II megalopa and in young crab. 1st mx. greatly simplified in structure. Both coxo- and basipodites remain unchanged except increase in serration. Enp. becomes rather rudimentary, only scaphognathite well developed. Both mxls. show adult structure already at I megalopa. 1st mxp. has 3-articulated basal portion, on which epip. present, being thin, hammer-shaped, and serrated around it. Exp. 2-articulate, both joints connected rectangularly to each other. Distal joint smaller than basal, tipped with 4 long hairs in addition to 1 lateral hair. Enp. thin, twisted along its long axis, expanded to its end. 1st mxp. shows no remarkable change in young crab stage. 2nd mxp. has unsegmented basal portion.

Fig. 22. *Charybdis bimaculata* MIERS. Zoea and megalopa.

(A) 1st ant. (zoea) ×72. (B) 1st ant. (megalopa) ×41. (C) 1st ant. (young crab) ×39. (D) enp. of 1st mx. (zoea) ×233. (E) 1st mx. (megalopa) ×72. (F) enp. of 2nd mx. (zoea) ×233. (G) 2nd mx. (megalopa) ×72. (H) enp. of 2nd mxp. (zoea) ×72. (I) 1st mxp. (megalopa) ×120. (J) 2nd mxp. (megalopa) ×72. (K) 2nd mxp. (young crab) ×33. (L) 3rd mxp. (megalopa) ×72. (M) 3rd mxp. (young crab) ×33. (N) cheliped (megalopa) ×26. (O) last leg (megalopa) ×21. (P) last leg (young crab) ×13.

Exp. 2-articulate, bears 4 terminal hairs. Enp. 4 articulate, distal 2 joints densely serrated, although basal joints smooth. 2nd mxp. also shows no change in later stages. 3rd mxp. becomes functional at first at I megalopa stage. Basal part unsegmented, epip. very slender, ending in 4 hairs. Enp. of 5 articulations. All joints only coarsely serrated at 1st stage, but very densely at 2nd stage and at young crab stage. Exp. 2-articulate, small projection on distal part of 1st joint. All mxpds. take adult form precociously at I megalopa.

Cheliped has no longitudinal ridge, rather rounded at I megalopa. Basipodite more or less swollen at its distal part, has no spine. First 3 ambulatory legs show usual structure, dactylus more or less pointed. Last leg differs from preceding ones. Dactylus paddle-shaped, bears 4 curly feelers near tip, with fine hairs all around it. Carpus curves distinctly. Coxopodite has large spinule on ventral side. Dactylus to propodus gradually flattened, resembling those of young crab already at II megalopa. Abdomen composed of 6 somites and telson. 1st somite largest, last one smallest. Lebour noted that the number of terminal hairs on the uropod tip of the last somite is peculiar to each species, while in the case of *Chary. bimac.*, the number of hairs gradually increases with development.

The characters of *Chary. bimac.* are as follows: (1) 2nd ant. composed of 2-articulate distal, 3-articulate basal, and 5 articulate middle parts at I megalopa, although middle part is 7-articulate at later stages, (2) paddle-shaped dactylus of last leg bears 4 curly feelers, (3) rostrum present throughout all megalopa stages, (4) abdomen composed of 6 somites, 1st somite largest, the last smallest, (5) lateral end of 5th somite very prominent.

20. *Portunus trituberculatus* Miers. 1st zoea. Fig. 23.

Characters: All kinds of carapacial spines present, 2nd ant. B_4-type, secondary chrom. only in 1st mxp. abdominal chrom. in 1st and 3rd to 5th somites each, telson A_2-type, hair formula 6–1, 2–4 (6), 4–1–1.

Dorsum 0.45 mm, rostrum 0.39 mm, perpendicular distance between tips 1.13 mm, carapace 0.47 mm, lateral spine 0.07 mm; abdomen 0.93 mm long, 0.17 mm wide, telson 0.42 mm.

Lateral spine very short, although present writer reported in his previous paper (Aikawa, 1929) that the lateral spine is absent. Rostrum nearly straight, but dorsum curves backwards. 2nd ant. B_4-type. Length of exp. nearly 2/5 of peduncle, thick at base, abruptly

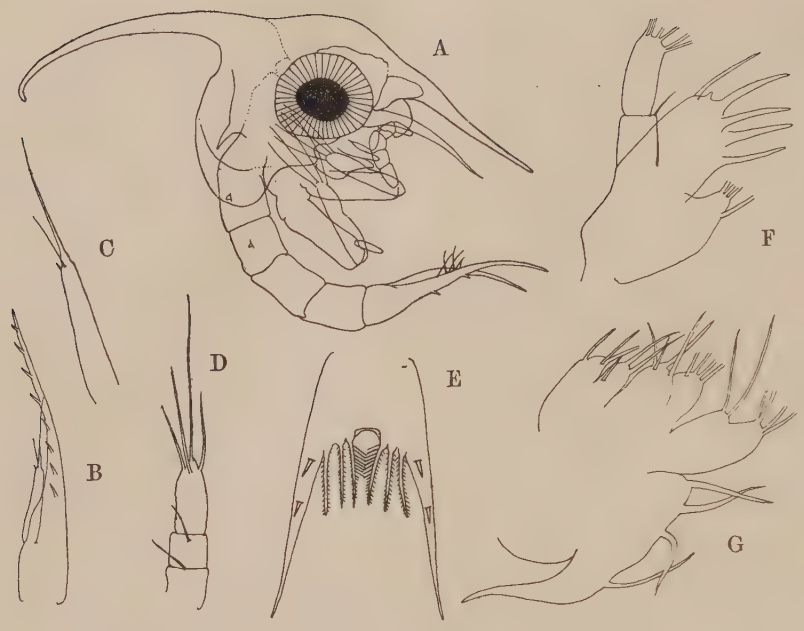


Fig. 23. *Portunus trituberculatus* MIERS. 1st zoea.
(A) lateral view ×37. (B) 2nd ant. ×121. (C) enp. of 2nd ant. ×233. (D) enp. of 2nd mxp. ×233. (E) telson ×72. (F) 1st mx. ×233. (G) 2nd mx. ×233.

slender to end. Peduncle furnished with fine teeth along one side. Enp. of 1st mx. has 2 joints, mode of serration here expressed by 6–1. All podites of 2nd mx. well bifurcated, mode of serration 2–4 (6) as usually seen in portunid larvae. Secondary chrom. present only in protopodite of 1st mxp. Enp. of 2nd mxp. has 3 joints. 1st and 2nd joints with 1 hair each on their distal edges, 3rd joint with 4 on tip. Abdominal chroms. present in 1st and in 3rd to 5th somites. Lateral knobs present on both 2nd and 3rd somites, lateral ends of all somites rather rounded. Telson A_2-type, 2 dorsal denticles on telson-fork. Telson-fork long, slender, smooth. 3 pairs of inner spines of same length, inner 3rd pair with 6 or 7 long hairs among short ones on inner side. Middle depression fairly deep.

21. *Portunus pelagicus* LINNÉ. 1st zoea and megalopa. Fig. 24.

Characters: All kinds of carapacial spines present, 2nd ant. B_1-type, secondary chrom. present only in 1st mxp., 1 abdominal chroms. involving 1st and 2nd somites and in 3rd to 5th somites each, telson A_2-type, hair formula 6–1, 2–4 (6), 5–1–1.

Dorsum 0.48 mm, rostrum 0.36 mm, perpendicular distance between tips 1.24 mm, lateral spine 0.04 mm, carapace 0.56 mm; abdomen 1.06 mm long, 0.11 mm wide, telson 0.40 mm.

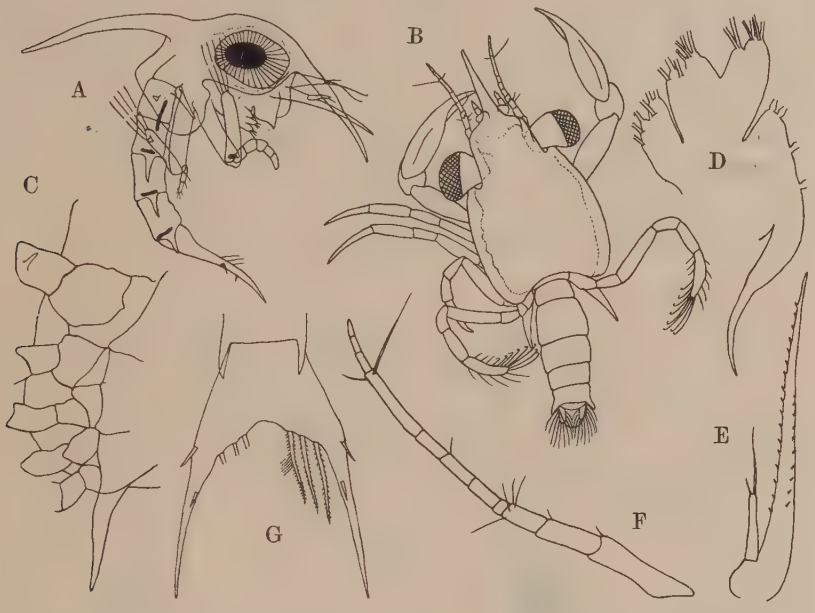


Fig. 24. *Portunus pelagicus* L. 1st zoea and megalopa.
(A) lateral view (1st zoea) ×39. (B) dorsal view (megalopa) ×10. (C) coxa of the last leg (megalopa) ×21. (D) 2nd mx. (zoea) ×233. (E) 2nd ant. (zoea) ×163. (F) 2nd ant. (megalopa) ×14. (G) telson (zoea) ×61.

Dorsum thick, bends backwards. Rostrum rather straight. Lateral spine very short, slender. 1st ant. bears only 2 aesthetes and a hair on tip. 2nd ant. B_4-type. Length of exp. only ¼ of peduncle, with 2 unequal hairs on tip. Peduncle long, slender, with fine teeth on both sides. Both mxls. similar to those of *Port. trit.* Secondary chrom. present in portopodite of 1st mxp. Enp. of 2nd mxp. has 3 joints. Both 1st and 2nd joints provided with 1 hair each, 3rd with 5 on tip. Lateral knobs present on both 2nd and 3rd abdominal somites, lateral ends of 3rd to 5th somites very prominent. 1 abdominal chrom. involving 1st and 2nd somites, and paired one in each somite from 3rd to 5th. Telson A_2-type, a denticle laterally near base of telson-fork, one more dorsally on it. 3 pairs of inner spines of nearly same length, inner 3rd pair with 6 long hairs among short ones on its inner side. Middle depression wide, but shallow.

Megalopa. Carapace rather rounded, frontal margin with long rostrum, becoming wider. 2nd ant. of 3 parts. Basal part 3-articulate, 1st joint longest, 3rd provided with ring of fine hairs near distal edge. Middle part 5-articulate, 8th joint with long stiff hair on outer distal edge, shorter hair on inner. Terminal part has 3 joints, all very small. Terminal joint tipped with 2 short stiff hairs. A very large spinous projection on coxa of last leg, and 1 hook on coxa of cheliped. Abdomen of 6 somites and telson. 2nd somite largest, narrowing to preceding and following somites. Lateral end of 5th somite prominent. Paddle-shaped dactylus of last leg with 4 long curly feelers on tip, 4 shorter ones on lateral side.

22. *Portunus* sp. Last zoea and megalopa. Figs. 25, 26.

Characters: All kinds of carapacial spines present, 2nd ant. B_4-type, secondary chrom. present in 1st mxp. abdominal chrom. distributed similarly as in zoea of *Port. pel.* L., hair formula 6–1, 2–4 (6), 5–1–1.

At last zoeal stage, dorsum measures 0.67 mm, rostrum 0.56 mm, perpendicular distance between tips 2.10 mm; lateral spine 0.06 mm.

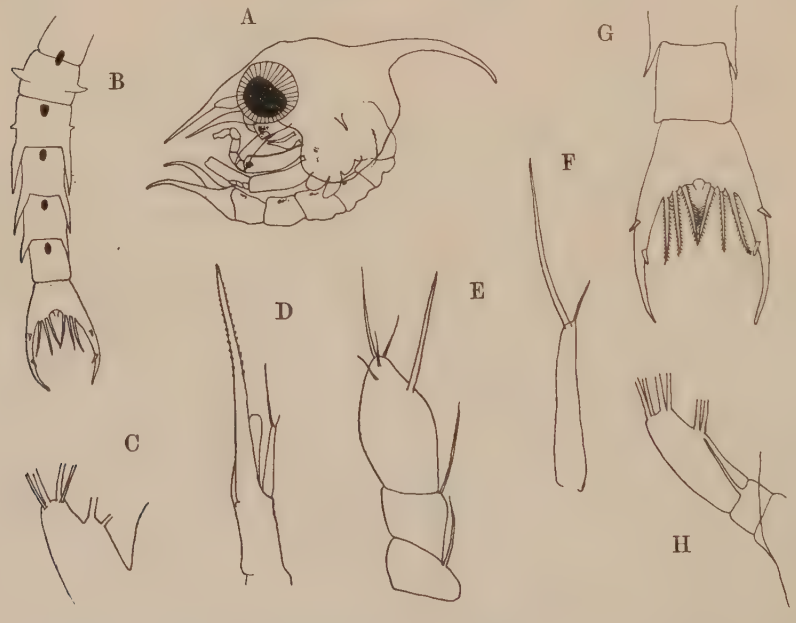


Fig. 25. *Portunus* sp. Last zoea.
(A) lateral view × 21. (B) abdomen × 17. (C) enp. of 2nd mx. × 180. (D) 2nd ant. × 43. (E) enp. of 2nd mxp. × 180. (F) enp. of 2nd ant. × 180. (G) telson × 43. (H) enp. of 1st mx. × 180.

carapace 0.99 mm; abdomen 2.86 mm long, 0.44 mm wide, telson 0.84 mm.

Dorsum curves fairly backwards, but rostrum straight. Both pointed at end. Lateral spine very short. 2nd ant. B_4-type. Peduncle pointed, straight, armed with fine teeth on both sides of distal half. Length of exp. ⅓ of peduncle, with long spinule and hair on tip. Length of enp. nearly same as that of peduncle at this last stage. Mandible densely pigmented. Enp. of 1st mx. has 2 joints and enp. of 2nd mx. only slightly bifurcated. Modes of serration on these enpds. similar to those of *Port. trit.* and *P. pel.* Secondary chrom. only in protopodite of 1st mxp. Segmentation and mode of serration on enp.

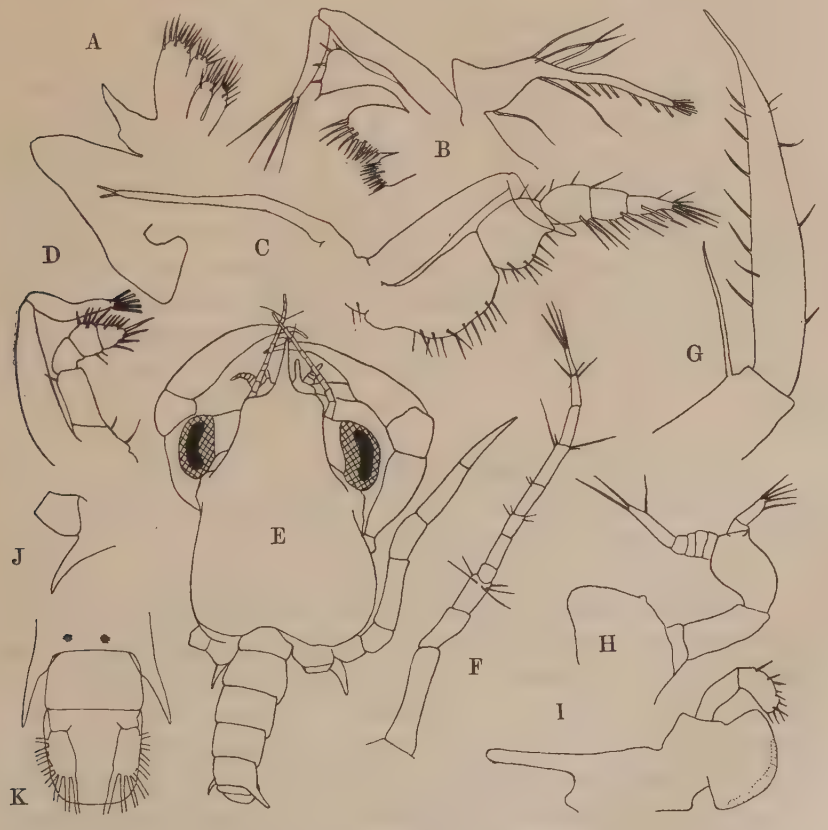


Fig. 26. *Portunus* sp. Megalopa.
(A) 2nd mx. ×61. (B) 1st mxp. ×43. (C) 3rd mxp. ×43. (D) 2nd mxp. ×43. (E) dorsal view ×17. (F) 2nd ant. ×43. (G) dactylus of last leg ×87. (H) 1st ant. ×43. (I) mandible ×61. (J) coxa of last leg ×33. (K) abdomen ×72.

of 2nd mxp. also similar to those of *Port. pel.* 3rd mxp. and 5 pairs of pereiopods well developed at this last stage. Abdomen composed of 6 somites and telson. Lateral knobs present on 2nd and 3rd somites, lateral ends of 3rd to 5th somites prominent. Telson A_2-type, with 1 denticle laterally near base of telson-fork, 1 dorsally on middle part. 3 pairs of inner spines and a pair of extra-hairs. Telson-fork slender, pointed.

Megalopa. Carapace nearly quadrate, but narrowing slightly towards front. Long pointed rostrum present, but neither dorsal nor lateral spines present. Spine on coxa of last leg very large. 1st ant. 2-branched. The basal part has 3 joints, enp. 2 and exp. 5. Sensory hairs on all segments of exp., its terminal joint with 2 long hairs on tip, 1 on lateral side. 2nd ant. single, composed of 11 joints. Basal part of 3 joints all very large. Middle part has 5 joints. Basal 4th joint smallest among antennal joints, 8th joint with 1 long stiff hair and 1 short on distal edge. Terminal part of 3-joints tapers. Last joint tipped with 4 stiff hairs. Mandible has palp of 2 joints. Enpds. of mxls. much reduced. Epip. of 1st mxp. has 4 terminal hairs. Enp. of 2nd mxp. has 5 joints. Enp. of 3rd mxp. also of 5 joints, its epip. tipped with 2 hairs. Basi-ischiopodite of cheliped bears small hook. Dactylus of last leg not paddle-shaped, without feelers. Abdomen of 6 somites and telson. Abdominal chrom. present in similar way to that observed in zoea of *Port. pel.* Uropod of last somite bears 4 terminal hairs.

23. *Erimacrus eisenbeckii* (Brandt). V zoea. Fig. 27.

Characters: All kinds of carapacial spines present, 2nd ant. B_1-type, telson A_2-type, hair formula 6–1, 3–5 (8), 5–1–1.

Marukawa, H. (1933). Rakusui Kai Si., vol. 28, p. 499, pls. 1–3.

At this last stage, dorsum 1.30 mm, rostrum 0.89 mm, perpendicular distance between their tips 3.36 mm, lateral spine 0.33 mm, carapace 1.47 mm; abdomen 2.11 mm long, 0.28 mm wide, telson 0.74 mm.

2nd ant. shorter than rostrum. Peduncle thick at base, slender at distal part, where it is armed with fine teeth on both sides. Exp. very small, only ¼ of peduncle, ending in 2 unequal hairs. Enp. of 1st mx. 2-articulate, mode of serration here expressed by 6–1. Enp. of 2nd mx. only slightly bifurcated, mode of serration 3–5 (8). Enp. of 2nd mxp. has 3 joints. Both 1st and 2nd joints with 1 hair on each distal edge,

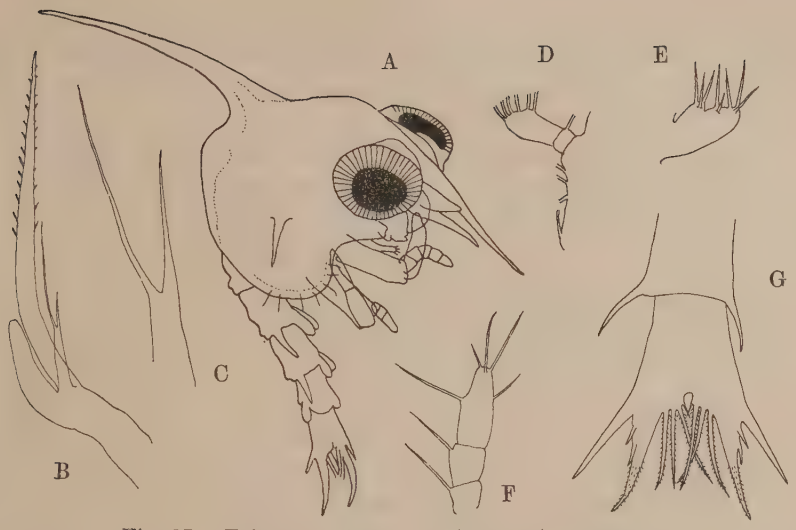


Fig. 27. *Erimacrus eisenbeckii* (BRANDT). Last zoea.
(A) lateral view ×39. (B) 2nd ant. ×61. (C) enp. of 2nd ant. ×377. (D) enp. of 1st mx. ×72. (E) enp. of 2nd mx. ×72. (F) enp. of 2nd mxp. ×72. (G) telson ×43.

3rd with 5 hairs. Lateral knobs on 2nd and 3rd somites, lateral ends of 3rd to 5th somites very prominent. Telson A_3-type, 3 outer denticulations all along lateral side. Uppermost denticulation largest, nearly equal to telson-fork, which is thick at base, pointed at end, covered with fine hairs all over distal half. 3 pairs of inner spines and 1 pair of extra-hairs. Middle depression narrow, but deep.

6th somite separated from telson at 2nd zoeal stage. Enp. of 2nd ant. first appears at 2nd stage, attaining only ¼ of peduncle at 3rd stage, ⅔ at 4th stage, equal to peduncle at last stage. Swimming hairs 8 in all at 2nd stage, 10 with 2 accessory hairs at 3rd stage, 12 with 4 accessory ones at 4th stage, 14 with 4 accessory ones at last stage. Rudiments of 3rd mxp. and pereiopods appear at 2nd stage.

Megalopa stage divisible into 2 substages. Important features however show no marked changes. At I megalopa stage, long thick rostrum, short spine on antero-lateral corner, 2 spines on postero-lateral portion, 2 on median dorsal portion. At 2nd stage all these projections except those on both antero-lateral corner entirely disappear. 2nd ant. separable into 3-articulate basal portions, 2-articulate middle portion, and 2-articulate terminal portion. Number of joints in each portion do not increase in later megalopa stage. Uropods of last somite bears 4 terminal hairs.

24. *Cancer gibbosulus* (DE HAAN) 1st zoea. Fig. 28.

Characters: All kinds of carapacial spines present, 2nd ant. B_4-type, telson A_2-type, hair formula 6–1, 3–3 (6), 5–1–1.

Rostrum 0.29 mm, dorsum 0.46 mm, perpendicular distance between their tips 1.07 mm, lateral spine 0.18 mm, carapace 0.41 mm; abdomen 0.72 mm long, 0.11 mm wide, telson 0.27 mm.

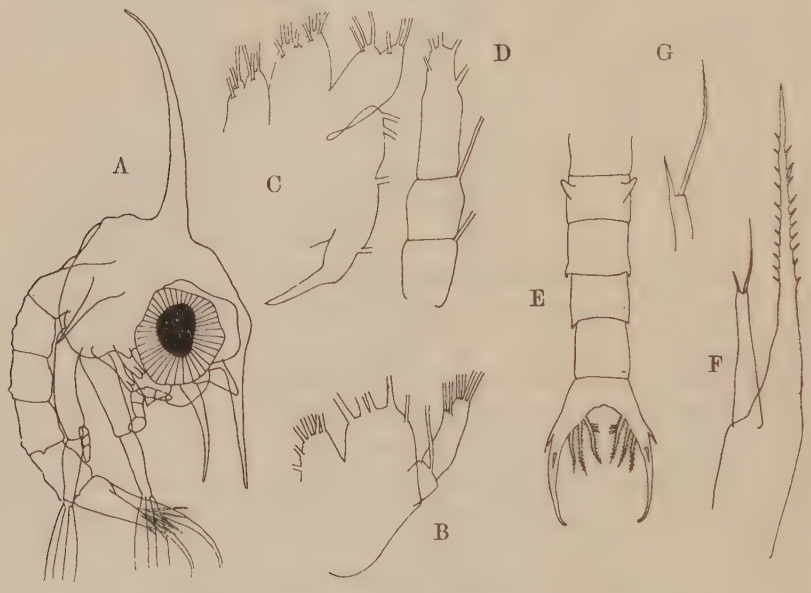


Fig. 28. *Cancer gibbosulus* (DE HAAN). 1st zoea.
(A) lateral view × 61. (B) 1st mx. × 233. (C) 2nd mx. × 233. (D) enp. of 2nd mxp. × 377. (E) abdomen × 72. (F) enp. of 2nd ant. × 467. (G) 2nd ant. × 377.

Rostrum straight, but dorsum bends backwards. Lateral spine fairly long. 2nd ant. B_4-type. Peduncle shorter than rostrum; thick at base, but pointed at end, armed with small teeth at its distal part. Exp. nearly ½ of peduncle with 2 unequal hairs on its rounded tip. Enp. of 1st mx. 2-articulate, mode of serration here 6–1. All podites of enp. of 2nd mx. deeply bifurcated, mode of serration on enp. 3–3 (6). Enp. of 2nd mxp. has 3 joints, mode of serration here expressed by 5–1–1. Zoea of *Cancer gibbosulus* greatly resembles those of Portunidae. Lateral knobs only on 2nd somite, lateral ends of 3rd to 5th somites slightly prominent. Telson A_2-type, 2 denticles on dorsal part of telson-fork, which is well developed and converges to end. Middle depression

shallow, but so wide that 3 inner spines are arranged considerably apart from each other on each side. 3rd pair has 5 long hairs among short ones on inner side, 2 long hairs on its outer side.

25. *Grapsizoea rutila* Aikawa (Atelecyclid zoea)
3rd zoea to megalopa. Fig. 29.

Characters: All kinds of carapacial spines present, 2nd ant. B_4-type, telson A_3-type, hair formula 6–1, 3–5 (8), 5–1–1.

At 3rd zoeal stage, dorsum 0.83 mm, rostrum 0.75 mm, perpendicular distance between their tips 2.50 mm, lateral spine 0.19 mm, carapace 1.04 mm; abdomen 1.91 mm long, 0.28–0.42 mm wide, and telson 0.69 mm.

Total of 8 swimming hairs on exp. of mxpds. at 3rd zoeal stage, 10 at 4th stage, 12 at last stage. Carapace fairly large. Dorsum curves backwards, pointed. Rostrum straight, lateral spine very short. In these points, this zoea closely resembles that of Portunidae. 1st ant. usual form, small projection of enp. already at 3rd stage. 2nd ant. B_4-type. Peduncle slender, armed with fine teeth on both sides of its distal half. Exp. ½ of length of peduncle at 3rd stage, more than ⅔ at last stage. Exp. tipped with 2 long smooth hairs. Mandible has broad chewing surface, densely pigmented. 1st mx. has 2-jointed enp., mode of serration here expressed by 6–1. All podites of 2nd mx. slightly bifurcated. Enp. bears 5 hairs on inner lobe, 3 on outer. Enp. of 2nd mxp. has 3 joints. Both 1st and 2nd joints with 1 hair each, 3rd with 5. 3rd mxp. and 5 pairs of pereiopods well developed at 3rd stage. Abdomen composed of 6 somites and telson, widest at 2nd somite, narrowing to preceding and following somites. Large lateral knobs present on 2nd and 3rd somites. Telson A_3-type, 2 lateral denticles near base of telson-fork, 1 on dorsal part. Telson-fork nearly straight, smooth; 3 pairs of inner spines, 2 pairs of extra-hairs.

At final stage, enp. of 2nd ant. becomes nearly of same length as peduncle. Enp. of 1st ant. increases in length, incompletely 2-jointed. Both 1st and 2nd mxpds. have very rudimentary epipds. 3rd mxp. 2-branched, but only incompletely segmented. Cheliped larger than following legs, chela very robust. All other features virtually unchanged.

Megalopa. Carapace nearly quadrate. Its frontal margin resembles that of zoea. Rostrum shorter than at zoeal stage. 1st ant. 2-branched. Basal part 3-jointed, 1st joint almost spherical, but other

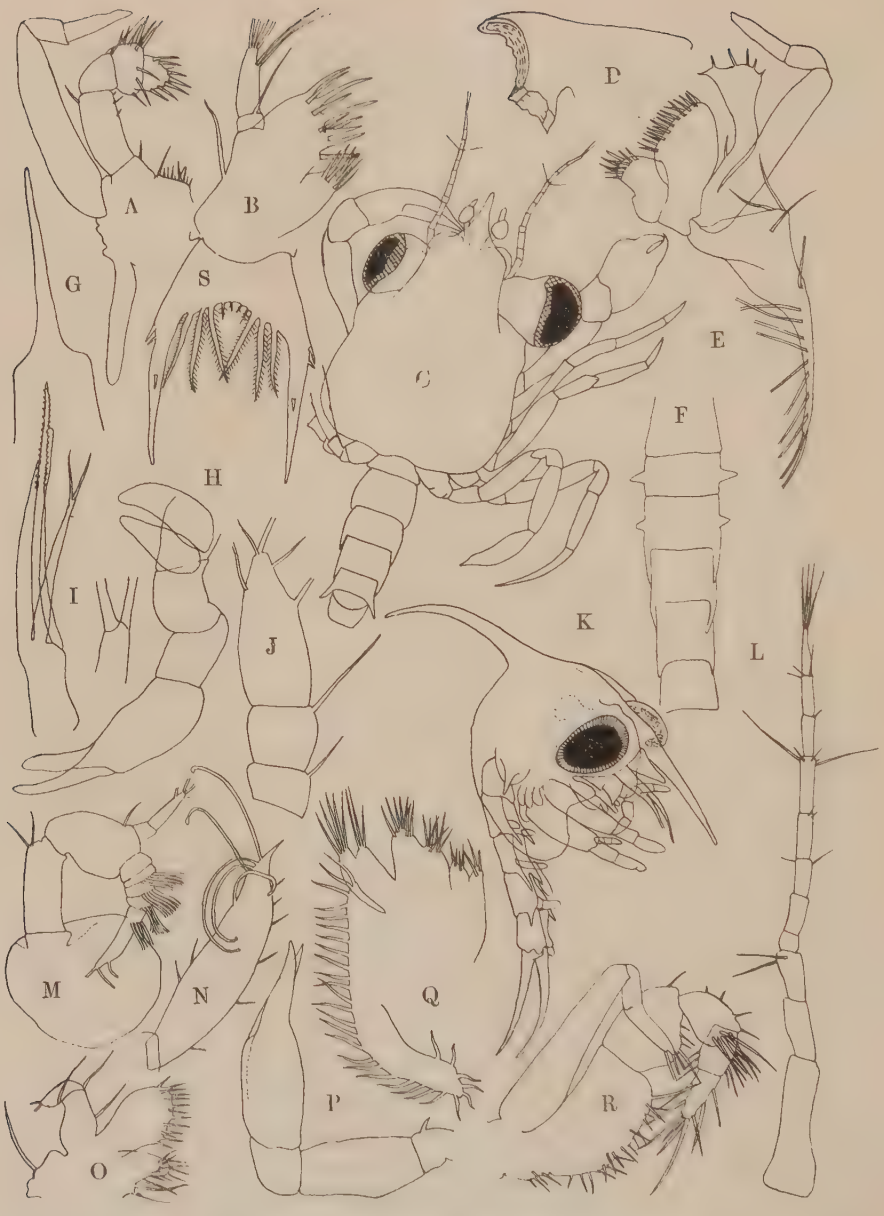


Fig. 29. *Grapsizoea rutila*. Last zoea and megalopa.
(A) 2nd mxp. (megalopa) × 48. (B) 1st mx. (III zoea) × 87. (C) megalopa × 13. (D) mandible (V zoea) × 61. (E) 1st mxp. (megal.) × 48. (F) abdomen (III zoea) × 26. (G) rostrum (V zoea) × 26. (H) cheliped (V zoea) × 39. (I) 2nd ant. (V zoea) × 61. (J) enp. of 2nd mxp. (III zoea) × 180. (K) V zoea × 21. (L) 2nd ant. (megal.) × 48. (M) 1st ant. (megal.) × 48. (N) dactylus of last leg (megal.) × 48. (O) 1st mx. (megal.) × 48. (P) cheliped (megal.) × 21. (Q) 2nd mx. (III zoea) × 87. (R) 3rd mxp. (megal.) × 48. (S) telson (III zoea) × 43.

2 elongated. Enp. 2-jointed, tapering, distal joint tipped with 3 hairs. Exp. has 5 joints; last joint with 2 terminal, 1 lateral hairs. 2nd ant. single, tapering, divisible into 3 portions. Basal portion has 3 joints, 3rd joint with 2 long stiff hairs on its distal edge. Middle portion 5 jointed. 4th joint smallest among antennal joints, 8th joint with 2 long and 2 short stiff hairs on its edge. Terminal portion is last 3 joints, each joint with 4 stiff hairs. Mandible with palp of single joint. Enpds. of both mxls. much reduced; that of 1st mx. with 3 long hairs on its lateral side, 2 short ones on its tip. 3rd mxp. usual form. Epip. of 1st mxp. has 2 terminal hairs besides long hairs around it. Basi-ischiopodite has small hook. Dactylus of last leg rather paddle-shaped, pointed at end, bears 5 curly feelers. Abdomen composed of 6 somites and small telson. Lateral ends of 3rd to 5th somites prominent as also observed in zoea.

Zoea and megalopa have many features in common with those of Portunidae. The hair formula differs from the latter group and the spinous projection is absent on the coxa of the last leg. In view of these characteristics, these larva may belong either to the family Atelecyclidae or to one of its allied families (for example Cancridae).

26. *Actumnus setifer* (DE HAAN) 1st zoea. Fig. 30.

Characters: All kinds of carapacial spines present, 2nd ant. A_2-type, telson A_3-type, hair formula 6–1, 3–5 (8), 5–1–1.

Dorsum 0.40 mm, rostrum 0.19 mm, perpendicular distance between their tips 1.15 mm, lateral spine 0.12 mm; carapace 0.66 mm long, 0.44 mm wide; abdomen 1.20 mm long, 0.17 mm wide, telson 0.44 mm.

Dorsum thick, hooked at its end. Rostrum and lateral spines rather short. 2nd ant. A_2-type. Peduncle and exp. nearly of same length, armed with fine teeth on both sides at their distal halves. In addition, exp. bears stout spinule on its middle part. Enp. of 1st mx. has 2 joints, mode of serration here expressed by 6–1. All podites of 2nd mx. well bifurcated. Enp. bears 5 hairs on inner lobe, 3 on outer. Expds. of mxpds. slightly segmented. Enp. of 2nd mxp. has 3 joints. Both 1st and 2nd joints with 1 hair each, 3rd with 5. Small buds of 3rd mxp. and 5 pairs of pereiopods already noticeable at this 1st zoeal stage. Abdomen composed of 5 somites and telson. Lateral knobs on 2nd and 3rd somites, lateral ends of 3rd to 5th somites more or less prominent. Telson A_3-type, with denticle and one hair laterally near base of telson-fork, one denticle on its dorsal side. Telson-fork long,

Fig. 30. *Actumnus setifer* (DE HAAN). 1st zoea.
(A) lateral view × 43. (B) 2nd ant. × 87. (C) 1st mx. × 180. (D) 2nd mx. × 270. (E) enp. of 2nd mxp. × 180. (F) abdomen × 43. (G) telson × 87.

pointed, covered all over with fine hairs. 3 pairs of inner spines of like length. Middle depression narrow, but fairly deep. Longest 3rd pair with 4 long hairs among short ones on its inner side, 1 long hair on outer side.

Zoea of *Actumnus setifer* (D. H.) resembles those of the genus *Pilumnus* and is included with the latter in the primitive zoeal group of the family Menippidae.

27. *Grapsus grapsus* LINNÉ. 1st zoea. Fig. 31.

Characters: Only lateral spines absent but dorsum and rostrum present, 2nd ant. B_4-type, secondary chrom. in 1st mxp., abdominal ones in each somite except telson, telson B-type, hair formula 5–1, 2–3 (5), 5–1–0.

Dorsum 0.30 mm, rostrum 0.25 mm, perpendicular distance between their tips 1.05 mm, carapace 0.61 mm; abdomen 0.73 mm long, 0.13 mm wide, telson 0.25 mm.

Larva fairly large. Dorsum and rostrum rather short. Rostrum straight, but dorsum slightly curved. 1st ant. bears 3 aesthetes, 2 short hairs on tip. 2nd ant. B_4-type. Peduncle thick, toothed coarsely at its distal half. Exp. ⅓ of length of peduncle, with 1 long hair and 3 short stiff hairs. Enp. of 1st mx. has 2 joints, mode of serration here

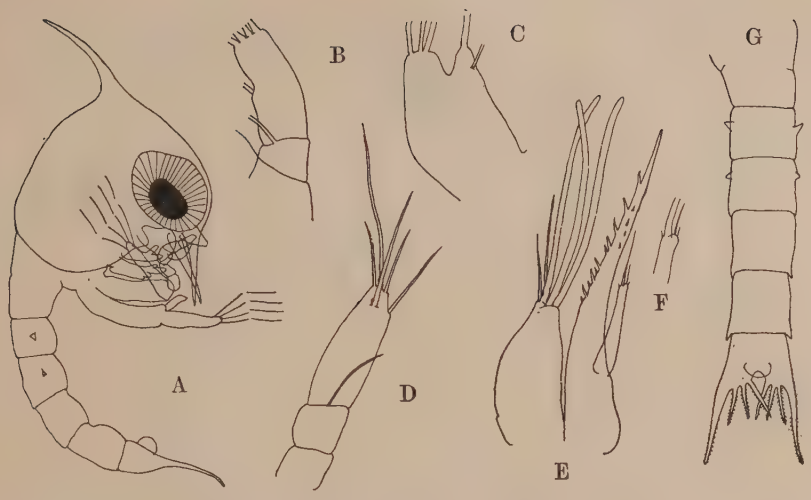


Fig. 31. *Grapsus grapsus* L. 1st zoea.
(A) lateral view × 40. (B) enp. of 1st mx. × 377. (C) enp. of 2nd mx. × 467.
(D) enp. of 2nd mxp. × 377. (E) 1st and 2nd ant. × 233.
(F) enp. of 2nd ant. × 467. (G) abdomen × 72.

expressed by 5–1. Enp. of 2nd mx. deeply bifurcated, bears 2 hairs on its outer lobe, 3 on its inner. Enp. of 2nd mxp. has 3 joints. 1st joint hairless, but 2nd 1 hair, 3rd 5 on tip. Secondary chrom. in 1st mxp. Lateral knobs on 2nd and 3rd somites. Abdominal chroms. in all somites except telson. Telson-fork pointed, covered with fine hairs. 3 pairs of inner spines of same length, middle depression fairly deep.

28. *Gaetice depressus* (DE HAAN). Last zoea and megalopa. Figs. 32, 33.

=*Platygrapsus depressus* DE HAAN. AIKAWA, 1929, p. 47.

At last zoeal stage, dorsum 0.94 mm, rostrum 1.02 mm, perpendicular distance between their tips 2.41 mm, carapace 1.24 mm; abdomen 2.94 mm long, 0.10 mm wide, telson 0.62 mm.

Dorsum and rostrum medium size, pointed. Lateral spine absent. Carapace fairly large. 2nd ant. B_2-type. Peduncle slender, armed with fine teeth along outer side at its distal two-thirds. Exp. long, with 1 spinule on middle part, slendering abruptly from this spinule to end. Enp. only ¼ of peduncle at this last stage. Enp. of 1st mx. shows 5–1 as mode of serration. All podites of 2nd mx. slightly bifurcated, 2 hairs on each lobe. Expds. of mxpds. have 12 swimming hairs. Enp.

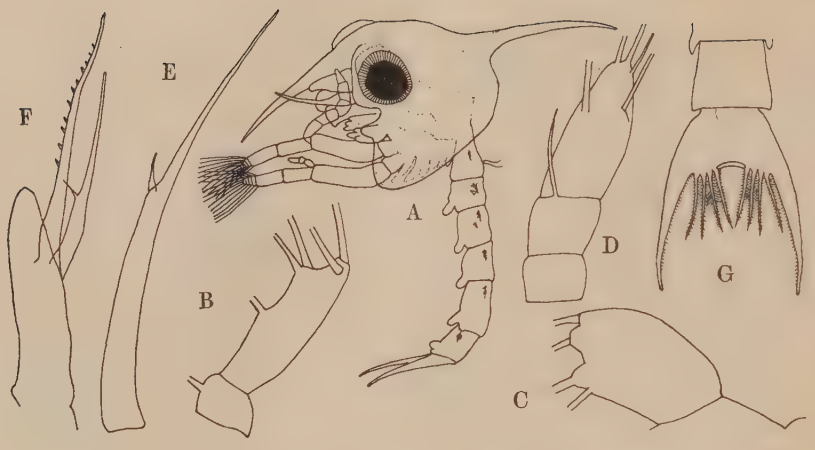


Fig. 32. *Gaetice depressus* (DE HAAN). Last zoea.
(A) lateral view ×21. (B) enp. of 1st mx. ×180. (C) enp. of 2nd mx. ×180.
(D) enp. of 2nd mxp. ×180. (E) enp. of 2nd ant. ×180.
(F) 2nd ant. ×87. (G) abdomen ×43.

of 2nd mxp. has 3 joints. Distal 3rd joint with 3 terminal, 2 lateral hairs, 2nd with 1, but 1st with none. 3rd mxp. and 5 pairs of pereiopods very small. Abdomen composed of 6 somites and telson. Lateral knobs on 2nd and 3rd somites, lateral end of 5th somite slightly prominent. Telson B-type. 4 pairs of inner spines of same length. 3rd pair with 4 or 5 long hairs among short ones on outer side, 5 or 6 long hairs on inner side. Telson-fork slender, pointed at end, finely serrated along its inner side.

Megalopa (Fig. 33). Carapace nearly quadrate. Rostral spine absent.

Middle depression on frontal margin of carapace wide. Neither dorsal nor lateral spines present. 1st ant. 2-branched. Basal part 3-jointed. 1st joint large, spherical, but 2nd and 3rd elongated. Enp. 3-articulate, tipped with 3 hairs. Exp. only 3-jointed, some sensory hairs on each joint. 2nd joint with 1 lateral hair, 3rd with 3 terminal hairs. 2nd ant. composed of 10 joints, very thick. Basal part 3-articulate, no serration on joints. 4th to 8th joints very small, closely jointed. 6th joint has ring of fine hairs around its distal edge. Last joint very small, tipped with a stiff hair. Sensory hairs present on 7th to 9th joints. Epip. of 1st mxp. has 1 terminal hair. Enp. of 1st mxp. flattened, 2 small teeth on its inner corner. Exp. 2-jointed, its

Fig. 33. *Gaetice depressus* (DE HAAN). Megalopa.
(A) 3rd mxp. ×40. (B) 2nd mxp. ×40. (C) 1st mxp. ×40. (D) 2nd mx. ×40. (E) cheliped ×43. (F) uropod of last somites ×87. (G) 1st ant. ×61. (H) 2nd ant. ×39. (I) coxa of last leg ×33. (J) dorsal view ×13. (K) abdomen ×43. (L) 1st mx. ×61.

distal joint has 4 hairs. Enp. of 2nd mxp. has 4 joints, 3rd and 4th joints thickly serrated. 2nd joint has only 1 hair, but 1st none. 1st joint of exp. has small tubercle, 2nd joint 4 terminal hairs. Epip. small, ending in 1 terminal hair. 3rd mxp. has 5-jointed enp. 1st to 4th joints rather cylindrical with stiff hairs along their inner sides.

Terminal joint becomes small stout hook, thickly chitinized, with a fine hair. Epip. large, densely serrated, with a terminal hair. Abdomen composed of 6 somites and telson. No lateral knob observed, but lateral end of 5th somite somewhat projected as noticed in zoea. Uropod of last somite bears 3 terminal hairs. Telson semicircular, 3 fine hairs on middle part of lower margin. No hook present on basi-ischipodite of cheliped, but knife-blade of chela (propodus and dactylus) densely chitinized, furnished with many short stiff hairs. Dactylus of last leg bears 4 feelers.

Enp. of 1st mx. of single joint, with 3 hairs on its inner side, 2 on outer. Enp. of 2nd mx. becomes completely rudimentary.

29. *Sesarma picta* DE HAAN. 1st zoea. Fig. 34.

Characters: Only lateral spines absent, 2nd ant. B_4-type, telson B-type, secondary chrom. only in 1st mxp. abdominal ones in all somites except telson, hair formula 5–1, 2–3 (5) 6–1–0.

Dorsum 0.17 mm, rostrum 0.15 mm, perpendicular distance between tips 0.63 mm, carapace 0.35 mm; abdomen 0.84 mm long, 0.20 mm wide, telson 0.25 mm.

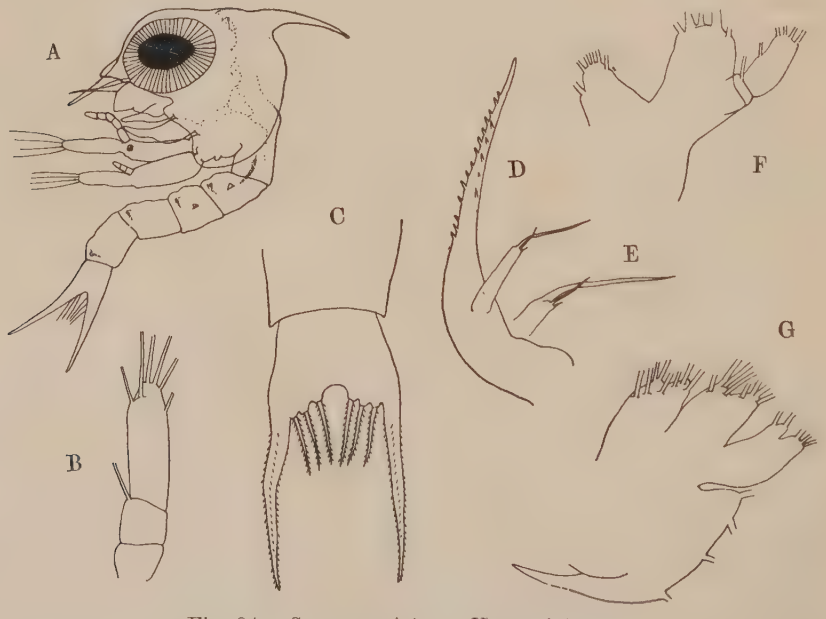


Fig. 34. *Sesarma picta* DE HAAN. 1st zoea.
(A) lateral view ×61. (B) enp. of 2nd mxp. ×377. (C) telson ×121. (D) 2nd ant. ×233. (E) enp. of 2nd ant. ×467. (F) 1st mx. ×233. (G) 2nd mx. ×233.

Larva medium size. Both carapacial spines thick at base, pointed at end. 2nd ant. longer than rostrum, B_4-type. Peduncle slightly curved, armed with teeth on distal part. Exp. only ¼ of length of peduncle, ends in a long hair and a short one. Enp. of 1st mx. 2-articulate, mode of serration here expressed by 5–1. All podites of 2nd mx. deeply bifurcated, mode of serration here 2–3 (5). Enp. of 2nd. mxp. has 3 joints. 1st joint hairless, but 2nd 1 hair on its distal edge, 3rd 6 on tip. Secondary chrom. only in 1st mxp. Lateral knobs on 2nd and 3rd somites. All abdominal somites have chromatophores. Telson-forks long, slender, parallel to each other, covered over with fine hairs. 3 pairs of inner spines present, middle depression fairly deep.

30. *Plagusia dentipes* DE HAAN. 1st zoea and megalopa.
Figs. 35, 36.

Characters: All kinds of carapacial spines present, 2nd ant. B_4-type, telson B-type, primary chrom. in both mxpds., abdominal ones in all somites and in telson, hair formula 5–1, 2–3 (5), 5–1–1.

Dorsum 0.42 mm, rostrum 0.45 mm, perpendicular distance between their tips 1.25 mm, lateral spine 0.21 mm, carapace 0.42 mm, abdomen 1.15 mm, telson 0.37 mm.

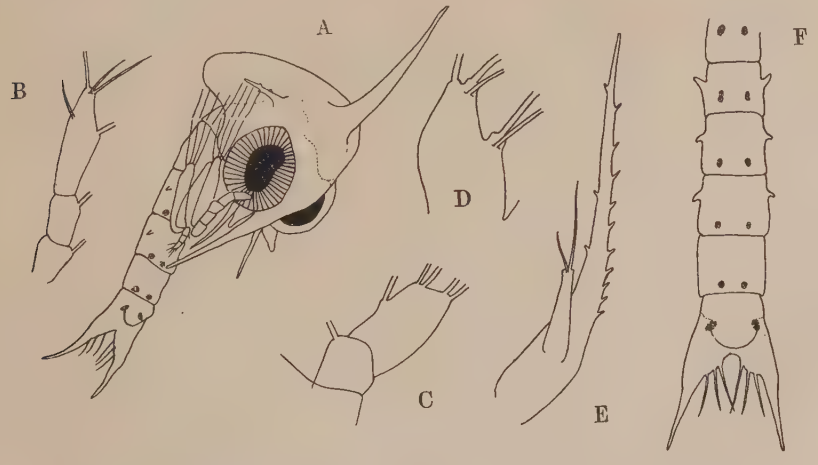


Fig. 35. *Plagusia dentipes* DE HAAN. 1st zoea.
(A) lateral view ×40. (B) enp. of 2nd mxp. ×213. (C) enp. of 1st mx. ×320. (D) enp. of 2nd mx. ×320. (E) 2nd ant. ×213. (F) abdomen ×61.

Dorsum thick at base, pointed at end. Rostrum nearly straight. Lateral spine straight, coarsely toothed. 1st ant. usual form, 2nd ant.

B_4-type. Peduncle curved, armed with teeth. Exp. short, only ¼ of peduncle, tipped with long spinule and a short hair. Enp. of 1st mx. 2-articulate, mode of serration here expressed by 5–1. Enp. of 2nd mx. biramous, 2 hairs on its small outer lobe, 3 on large inner lobe. Primary chroms. in both mxpds. Enp. of 2nd mxp. has 3 joints. 1st and 2nd joints with 1 hair on each distal edge, 3rd with 3 on tip and with 1 on each lateral side.

Lateral knobs present on 2nd to 4th somites. Abdominal chroms. present in all somites and in telson. Telson B-type. 3 pairs of inner spines of same length. Middle depression wide, but shallow. Telson-fork thick at base, pointed at end.

Megalopa (Fig. 36). The megalops of I stage usually form swarms in the open seas from late winter to spring. Those of II stage live in great abundance on floating weeds and timbers from spring to early summer. Megalops are carried to the coast with weeds and timbers and dammed up there. I megalops are almost transparent, pale greenish, but II megalops become rather brownish, of colour similar to floating weeds. Megalops change to young crab through 2 stages, although they show 3 modes in their body lengths. II megalop,

Megalopa Stage	Carapace		Abdomen	
	length mm	width mm	length mm	width mm
Stage I	5.1	3.5	2.7	1.2
„ IIa	7.5	7.1	4.3	2.6
„ IIb	9.0	6.2	5.0	3.0
Young crab	10.1	9.0	—	—

which is of remarkable size, are called "Saba-gani". Fishermen expect a good catch wherever these Saba-gami are found in great numbers. At the megalopa stage, both mxls. and 1st to 3rd mxpds. have already acquired their adult forms. Carapace nearly quadrate and slightly narrows towards its anterior end. Rostrum present at I megalopa stage, but disappears at II stage. 2nd ant. composed of terminal, middle, and basal parts. Terminal part 3-articulate, slender. Basal part also 3-articulate, 3rd joint has ring of short hairs around its distal edge. Middle part 5-articulate at I stage, 8 at II stage and in young crab. Last joint bears 3 sensory hairs on its tip at 1 stage, 5 at II stage and in young crab. All joints of cheliped smooth at I

stage, but at II stage its merus and propodus become thick where the beaded ridge develops in the young crab. Ischium of cheliped has large hooked spine at I stage. Spine becomes smaller and straight at II stage, finally in young crab hardly distinguishable from the hairs around it. Abdominal somites wider than long, ridged along median line at each somite. Short tooth on middle end of 5th somite. Lateral ends of 1st to 5th somites more or less projected.

Fig. 36. *Plagusia dentipes* DE HAAN. Megalopa and young crab.
(A) dorsal view (I megalopa) ×7. (B) dorsal view (II megal.) ×5. (C) frontal margin of carapace (II megal.) ×5. (D) dorsal view (young crab) ×3. (E) 2nd ant. (I megal.) ×24. (F) cheliped (I megal.) ×9. (G) cheliped (II megal.) ×9. (H) cheliped (young crab) ×9.

Part III. Larval characteristics of some important families

The writer attempts here to describe the larval characters of some important families, refering to zoeas described in Japan and abroad. As listed in Table I–IV, they total about 70 genera and 150 species.

(1) Family Dromiidae (Table I, 1).

Zoea of *Dromia vulgaris* has no stable brown chromatophores, the colour pattern of its body being very similar to those of both Macrura and Anomura. 2nd antenna F-type, telson G-type. Excepting the fairly large spinous process on the basal part of the 2nd antenna it is almost impossible to separate dromiid zoea from those of Macrura and Anomura. Endopodite of 2nd maxilla single, but endopodite of 1st maxilla 2-articulate. In these points, dromiid larva can be distinguished from homolid zoea.

Table I. List of larval characters

No.	Species	Reference	Carapacial spines		
			Ros.	Dor.	Lat.
1.	*Dromia vulgaris* M.-EDWS.	LEBOUR(5), p. 241, pls. 1–5	0	×	×
2.	*Latreillia phlangium* D. H.	Fig. 3.	0	×	×
3.	*Parahomola japonica* PAR.	Fig. 4.	0	×	×
4.	*Homola* sp.	WILLIAMSON(2), p. 543.	0	×	×
5.	*Homola* sp.	Fig. 5.	0	×	×
6.	*Ethusa macerone* ROUX	WILLIAMSON(2), p. 561.	0	0	0
7.	*Dorippe* sp.	GURNEY(1), p. 194.	0	0	0
8.	*Dorippe granulata* D. H.	Fig. 6.	0	0	×
9.	*Dorippe* sp. A.	Fig. 7.	0	0	×
10.	*Dorippe* sp. B.	Fig. 8.	0	0	×
11.	*Calappa lophos* (HERBST)	Fig. 9.	0	0	0
12.	*Ebalia tuberosa* (PEN.)	WILLIAMSON(2), p. 557. LEBOUR(3), p. 539.	0	×	0
13.	*E. longipedata* ORT.	Fig. 10.	0	×	0
14.	*E. cranchii* LEACH	LEBOUR(3), p. 540.	0	×	×
15.	*E.* sp.	JÖRGENSEN(1), p. 157.	×	×	0
16.	*Leucosia signata* LEACH	GURNEY(3), p. 284.	0	×	0
17.	*Ilia* sp.	CANO(2), p. 527.	—	—	—
18.	*Philyra pisum* D. H.	AIKAWA(1), p. 34.	0	×	×
19.	*P. tuberculata* STIMPSON	ibid. p. 35.	0	×	×

(2) Family Homolidae (Table I, 2–5).

Zoeas of *Latreillia phalangium*, *Parahomola japonica*, and 2 unknown species of G. *Homola* described. These zoeas possess the F-type of 2nd antenna and G-type of telson. The spinous process on the basal part of 2nd antenna is fairly large. It is also noteworthy that in this family the endopodite of the 2nd maxilla is 2-articulate, and its terminal joint furnished with more hairs than its basal joint. In addition, the endopodite of the 2nd maxilliped has 4 or 5 joints. In these respects, zoeas of the Homolidae can be determined, although they can be grouped into *Lithozoea* together with dromiid larva. The cephalothorax of G. *Homola* bears many spinous processes large or small. Carapace is 2-lapped, each lap being finely toothed along its lower margin in the Homolidae.

(3) Family Dorippidae (Table I, 6–10).

Zoeas of *Ethusa macerone*, *Dorippe granulata*, and 3 unknown

of the Dromiidea and the Oxystomata.

	2nd antenna	Telson	mxp.-chrom.		Hair Formula		
			1st mxp.	2nd mxp.	1st mx.	2nd mx.	2nd mxp.
1	E	G	×	×	4–2	7	?
2	E	G	×	×	5–1	3-4(7)	5–2–0–0
3	E	G	×	×	5–1	2-6(8)	5–2–1–1
4	E	G	×	×			
5	E	G	×	×	5–1	2–4(6)	5-3-1-3-0
6	A	C	–	–			
7	A_3	C	–	–			
8	A_3	C	×	×	4–0	4	3–1–0
9	A_3	C	×	×	4–0	4	3–1–0
10	A_3	C	×	×	4–0	4	4–1–0
11	B_2	A_2	×	×	4–0	2–5(7)	4–1–1
12	D	E	×	×			
13	D	E	–	–	4	3	3
14	D	E	×	×			
15	D	E	–	–			
16	D	E	0_1	0_1			
17	D	E	–	–			
18	D	E	0_1	0_1	4–0	3	1–0
19	D	E	0_1	0_1	4–0	3	2–0

species of *Dorippe* are described. In the remarkable length of both dorsum and rostrum, these zoeas resemble Porcellana larva. Stable brown chromatophores are also absent. Here, 2nd antenna is also F-type, but its spinous process on the basal portion also well developed. Telson is a peculiar C-type. These larvae, which are grouped into *Ethusozoea,* are easily distinguished from other Brachyura larvae. The species can be determined only by the presence or absence of carapacial spines and other detailed structures, of which it is difficult to be sure in the previous papers. All kinds of carapacial spines are present in the larva of *Ethusa,* while the lateral spines alone are absent in *Dorippe.* The endopodite of 1st maxilla is 2-articulate, but its basal joint is hairless. The endopodite of 2nd maxilla is usually single. Endopodite of 2nd maxilliped has 3 joints, its basal joint hairless. Ethusozoeas resemble the usual Brachyura larvae rather than those of the Dromiidae and the Homolidae.

(4) Family Calappidae (Table I, 11).

The calappid zoea has already attained typical brachyuran form, differing from any zoeas of the Oxystomata. 2nd antenna is B-type, telson A-type, hence grouped into *Grapsizoea.* It is easily distinguished from other members of *Grapsizoea* merely by absence of the stable brown chromatophores in both maxillipedes and in abdomen. Endopodite of 1st maxilla has 2 joints, its basal joint hairless. Endopodite of 2nd maxilla bifurcated. Endopodite of 2nd maxilliped has 3 joints, all with hair each. Colour pattern of body almost same as those of both Dromiidae and Homolidae.

(5) Family Leucosiidae (Table I, 12–19).

Zoeas of only a few genera are known from this large family. The presence and absence of carapacial spines is irregular, while all have the D-type of 2nd antenna, which is regarded as a deviation. Telson of E-type resembles the *Pasiphaë*-telson and retains the primitive features. Endopodite of 2nd maxilla generally single, endopodite of 2nd maxilliped only 1 or 2 articulate, never 3. Maxillipedal chromatophores are of primary character. The zoeas of this family, which are always called *Leucozoea,* are easily distinguishable from other brachyuran larvae. The species may be determined by the grouping of chromatophores in maxillipedes and in abdomen, and by the presence or absence of carapacial spines. The *Leucozoea* is at all events a deviated group of brachyuran zoeas.

Ortmann assumed that the Raninidae and the Leucosiidae together

form a particular group, and the Matutidae, the Calappidae, and the Orythyidae another group. The Dorippidae differs from either, although it is closer to the latter group than the former. Considering the relationship between these groups based on their larval characters, the zoeas of the Calappidae and the Dorippidae differ greatly from the Leucosiidae, showing besides close affinity with the usual brachyuran group. In this way, the zoeas of the Oxystomata can be separated into 3 groups, namely, *Leucozoea, Ethusozoea,* and *Grapsizoea. Leucozoea* may be related to the *Lithozoea* of the Homolidae and the Dromiidae on one hand, and to the *Grapsizoea* of the Calappidae with the usual brachyuran zoea on the other.

(6) Family Corystidae (Table II, 1).

The larva of *Corystes cassivelanus* is well known among this family. All kinds of carapacial spines are present. 2nd antenna B_4-type, telson also A_1-type. Secondary chromatophores present in both maxillipedes. Endopodite of 2nd maxilla probably single (Williamson, 2, p. 545, fig. 468), the lateral knobs occuring only on 2nd abdominal somite (Lebour, 3, p. 525). In addition, the zoea is rather more advanced in development than in most like stage of the Brachyrhyncha group (Lebour, 3, p. 527). The rudiments of the 3rd maxilliped and 5 pairs of pereiopods may therefore be present already at the 1st larval stage. In these respects, the zoea of *Corystes cassiv.* greatly resembles the larvae of Majidae, especially the group represented by G. *Maia* and certain others, Ortmann placed this family with the Inachidae and the Majidae in the Majoidea. The zoea of the Corystidae clearly differ from the larvae of Cancroidea.

(7) Family Hymenosomidae (Table II, 2–4).

The zoea of this family is the *Hymenozoea,* being characterized by the D-type of 2nd antenna and telson. Rostrum alone is present, its shape being very peculiar. Primary chromatophores are present in both maxillipedes. Endopodite of 1st maxilla has 2 joints, its basal joint with a hair. Endopodite of 2nd maxilla is single. Endopodite of 2nd maxilliped has 3 joints. Lateral knobs absent on abdomen. The Hymenosomidae, which may be a deviated group, seems to be related to the Leucosiidae rather than to the Cancroidea.

(8) Family Inachidae (Table II, 5–22).

Zoeas of the Inachidae generally have the A_3-type of 2nd antenna. Telson generally A_1-type, but less frequently A_2 or A_3-type. The zoeas are separable into 2 groups, the one with only a rostrum, the

Table II. List of larval

No.	Species	Reference	Carapacial spines		
			Ros.	Dor.	Lat.
1.	*Corystes cassivelanus* (PENN.)	WILLIAMSON (2), p. 544. LEBOUR (3), p. 526.	0	×	0
2.	*Rhynchoplax messor* STIMPSON	AIKAWA (1), p. 36.	0	×	×
3.	*Trigonoplax unguiformis* D. H.	ibid., p. 37.	0	×	×
4.	*Halicarcinus septentrionalis* Y.	ibid., p. 37.	0	×	×
5.	*Stenorhynchus unguif.* M.-EDWS.	CANO (2), p. 527.	×	0	×
6.	*Paratymolus pubescens* D. H.	Fig. 12.	0	0	×
7.	*Achaeus* sp. A	Fig. 13.	×	0	×
8.	*Achaeus* sp. B	Fig. 14.	×	0	×
9.	*Inachus dorsettensis* (PENN.)	WILLIAMSON (2), p. 530. LEBOUR (3), p. 546.	×	0	×
10.	*I. rostratus* (L.)	WILLIAMSON (2), p. 532.	×	0	×
11.	*I. cranchii* (LEACH)	ibid., p. 530.	×	0	×
12.	*I. dorhynchus* (LEACH)	LEBOUR (3), p. 547.	×	0	×
13.	*I. leptocheirus* LEACH	ibid., p. 548.	×	0	×
14.	*I. scorpio*	CANO (2), p. 527.	×	0	×
15.	*Macropodia egyptia* M.-E.	LEBOUR (3), p. 550.	×	0	×
16.	*M. rostratus* (L.)	ibid., p. 550.	×	0	×
17.	*M. longirostris* (FABR.)	ibid., p. 549.	×	0	×
18.	*Inachus* sp.	CANO (2), p. 527.	×	0	×
19.	*Pleistacantha san.-joh.* MIERS	Fig. 11.	0	0	×
20.	*Huenia proteus* D. H.	Fig. 15.	0	0	×
21.	*Pugettia quadridens* D. H.	AIKAWA (1), p. 38.	0	0	×
22.	*Acanthonyx* sp.	CANO (2), p. 527.	0	0	×
23.	*Hyas araneus* (L.)	WILLIAMSON (2), p. 521. LEBOUR (4), p. 93.	0	0	0
24.	*H. coarctatus* LEACH	WILLIAMSON (2), p. 526.	0	0	0
25.	*Maia squinado* HERBST	LEBOUR (3), p. 542.	0	0	0
26.	*M. verrucosa* M.-EDWS.	WILLIAMSON (2), p. 538.	0	0	0
27.	*M.* sp.	ibid., p. 539.	0	0	0
28.	*Chionecetes opilio* FABR.	Fig. 17.	0	0	0
29.	*Herbstia* sp.	CANO (2), p. 527.	0	0	×
30.	*Pisa biaculeata* MONTAGU	LEBOUR (3), p. 544, (4), p. 94.	0	0	×
31.	*Naxia hystrix* MIERS	Fig. 16.	0	0	0
32.	*Eurynome aspera* (PENNANT)	LEBOUR (3), p. 543.	0	0	0
33.	*Eurynome* sp.	CANO (2), p. 527, WILLIAMSON (2), p. 534.	0	0	×
34.	*Tiarinia cornigera* LATR.	Fig. 18.	0	0	×
35.	*Lissa* sp.	CANO (2), p. 527.	×	0	×

Note: 0 = presence, × = absence,

characters of the Majoidea.

No.	2nd antenna	Telson	Mxp.-chrom.		Hair Formula		
			1st mxp.	2nd mxp.	1st mx.	2nd mx.	2nd mxp.
1	B_4	A_1	0_2	0_2		Single	4-1-1
2	D	D	0_1	0_1	4-1	5	5-1-1
3	D	D	0_1	0_1	4-1	5	5-1-1
4	D	D	0_1	0_1	4-1	5	5-1-1
5	A_3	A_1	—	—			
6	B_2	B	×	×	6-1	3-5(8)	2-0-0
7	A_3	A_1	—	—	3-0	4	4-0-0
8	A_3	A_1	—	—	3-0	4	4-0-0
9	A_3	A_1	×	0_1			
10	A_3	A_1	—	—			
11	A_3	A_1	—	—			
12	A_3	A_1	0_1	0_1			
13	A_3	A_1	×	0_1			
14	A_3	A_3	—	—			
15	A_3	A_1	0_1	0_1			
16	A_3	A_1	×	0_1			
17	A_3	A_1	0_1	0_1			
18	A_3	A_1	—	—			
19	A_3	A_3	—	—	6-1	5	4-1-0
20	A_3	A_1	×	0_1	5-0	4	4-1-0
21	A_3	A_2	0_1	0_1	4-1	4	3-1-0
22	A_3	A	—	—			
23	B_5	A_2	—	—			
24	B_5	A_2	0_1	0_1			
25	B_5	A_3	0_1	0_1			
26	B_5	A_3	—	—			
27	B	A_1	—	—			
28	B_5	A_2	—	—	5-1	2-3(5)	5-×-×
29	A_3	A_1	—	—			
30	A_3	A_1	0_2	0_2			
31	A_3	A_1	—	—	6-1	5	4-1-0
32	B_4	A_3	0_1	0_1			
33	B_4	A_3	—	—			
34	A_3	A_3	—	—	6-1	3-5(8)	6-1-1
35	A_3	A_1	—	—			

—=not ascertained.

other with both rostrum and dorsum. Endopodite of 2nd maxilla is always single. Primary chromatophores are present in both maxillipedes or in one of them. Lateral knobs are present on 2nd somite alone. A characteristic of this group is that the rudiments of the 3rd maxilliped and 5 pairs of pereiopods are present already at 1st larval stage. The zoeas of *Stenorhynchus*, *Achaeus*, *Inachus*, and *Macropodia* belong to the 1st group. The 2nd group comprises the larvae of *Pugettia*, *Huenia*, *Pleistacantha*, and *Acanthonyx*. The zoea of *Acanthonyx* has both dorsum and rostrum, although the latter is minute and rudimentary. The zoea of *Acanthonyx* is therefore a transition form between these 2 groups. The division based on the larval characters is not in entire agreement with the classification of the adult form, but the 1st group undoubtedly corresponds to the subfamily Inachinae and the 2nd group to the Acanthonychinae.

(9) Family Majidae (Table II, 23–33).

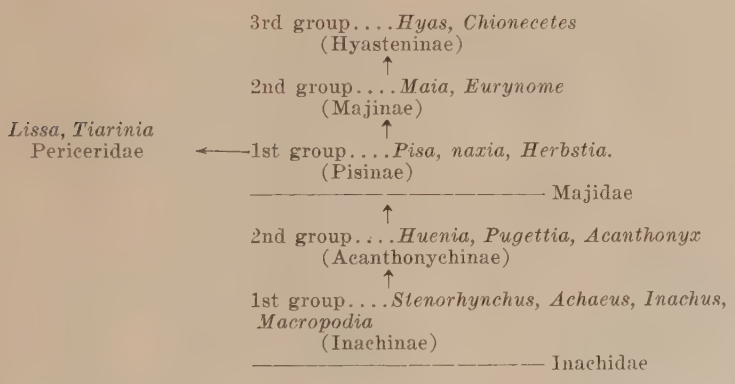
The larvae of the Majidae are not so uniform in character as those of the Inachidae. They are as a whole separable into 3 groups. The 1st group being composed of the larvae of *Pisa*, *Naxia*, and *Herbstia*, the 2nd group of *Maia* and *Eurynome*, and the 3rd of *Hyas* and *Chionecetes*. In the 1st group, both dorsum and rostrum are present, but the laterals either absent or very rudimentary (*Herbstia*). As assumed so far from the larval characters of *Pisa*, the maxillipedal chromatophores are of secondary character, the endopodite of the 2nd maxilla being single. Rudiments of the 3rd maxilliped and pereiopods are present in the 1st stage, the lateral knobs occurring only on the 2nd somite. The larval characters of the 1st group are therefore similar to those of the 2nd group of the Inachidae, except the character of its maxillipedal chromatophores. Both 2nd and 3rd group, which have B-type 2nd antenna and A-type telson, are grouped in the *Grapsizoea*. In the 2nd group, the lateral knobs occur on the 2nd abdominal somite alone, while in the 3rd group they occur on both 2nd and 3rd somites. So far as assumed from the larval characters of *Chionecetes*, the endopodite of the 2nd maxilla is bifurcated in 3rd group, while probably single in 2nd group. In addition, the lateral spines of the 2nd group are much shorter than those of the 3rd group. Both 2nd and 3rd groups are easily distinguishable from other *Grapsizoeas* by the presence of primary chromatophores in the maxillipedes. Lebour suggested the advisability of keeping the subfamily Pisinae for *Pisa*, together with certain foreign crabs, including *Lissa*, which according to Cano, closely

resembles *Pisa* in development, and of placing *Hyas* in a new subfamily (Lebour, 4, p. 96), with all of which the present writer agrees except his treatment of *Lissa*.

(10) Family Periceridae (Table II, 34, 35).

The larvae of *Lissa* sp. and *Tiarinia cornigera* are described. Both 2nd antenna and telson are of A-type. *Lissa* has only the dorsum, whereas *Tiarinia* has both dorsum and rostrum. The larva of *Lissa* strongly resembles those of the 2nd group of Inachidae. The writer has regarded here the larva of *Tiarinia* as representative of this family. Endopodite of 2nd maxilla biramous. Rudiments of 3rd maxilliped and pereiopods absent at 1st stage, whence the larva of the Periceridae retains to a considerable extent the primitive features, being related to the 1st group of Majidae more closely than to either the 2nd or 3rd groups.

The zoeas of the Majoidea may be related in the manner shown in the following scheme:



The 1st group of Inachidae (Inachinae) is the most primitive. The pericerid group and the 2nd group of the Majidae (Majinae) may have originated from the 1st group of the Majidae (Pisinae). The 3rd group of the Majidae (Hyasteninae) may be the most highly developed of the Majoidea. The 2nd group of the Inachidae (Acanthonychinae) and the 1st group of the Majidae (Pisinae) are very closely related.

(11) Families Polybiidae (Table III, 1), Portunidae (2–14), Thalamitidae (15, 16), Parthenopidae (17, 18), Atelecyclidae (19, 20), Carcinidae (21, 22), Cancridae (23–25) and Thiidae (26).

All zoeas of these families have the B-type of 2nd antenna and

Table III. List of larval

No.	Species	Reference	Carapacial spines		
			Ros.	Dor.	Lat.
1.	*Polybius henslowi* LEACH	LEBOUR(3), p. 516.	0	0	0
2.	*Bathynectes longipes* RISSO	ibid., p. 515, (4), p. 94.	0	0	0
3.	*Callinectes sapidus* RATHBUN	CHURCHILL(1), p. 98.	0	0	0
4.	*Portunus puber* (L.)	WILLIAMSON(2), p. 514. LEBOUR(3), p. 506.	0	0	0
5.	*P. corrugatus* (PENN.)	LEBOUR(3), p. 509.	0	0	0
6.	*P. pusillus* LEACH	WILLIAMSON(2), p. 517. LEBOUR(3), p. 511.	0	0	0
7.	*P. arcuatus* LEACH	LEBOUR(3), p. 510.	0	0	0
8.	*P. marmoreus* LEACH	ibid., p. 512.	0	0	0
9.	*P. holsatus* FABR.	WILLIAMSON(2), p. 496. LEBOUR(3), p. 513.	0	0	0
10.	*P. depulator* L.	WILLIAMSON(2), p. 496.	0	0	0
11.	*P. trituberculatus* MIERS	Fig. 23.	0	0	0
12.	*P. pelagicus* L.	Fig. 24.	0	0	0
13.	*P. maenus* (L.)	WILLIAMSON(2), p. 503.	0	0	×
14.	*P. plicatus* COUCH.	WILLIAMSON(2), p. 511.	0	0	×
15.	*Charybdis 6-dentata* HERBST	Fig. 20.	0	0	0
16.	*C. bimaculata* MIERS	Figs. 21, 22.	0	0	0
17.	*Lambrus anguilifrons* LATR.	CANO(2), p. 527.	0	0	0
18.	*L. validus* DE HAAN	Fig. 19.	0	0	0
19.	*Atelecyclus septend.* (MONT.)	LEBOUR(3), p. 524.	0	0	0
20.	*Erimacrus eisenbeckii* (BDT.)	Fig. 27.	0	0	0
21.	*Perimela denticulata* (MONT.)	LEBOUR(3), p. 519.	0	0	0
22.	*Carcinus maenus* PENNANT	WILLIAMSON(1).	0	0	×
23.	*Cancer pagurus* L.	WILLIAMSON(2), p. 485. LEBOUR(3), p. 522.	0	0	0
24.	*C. amaenus* (HERBST)	CONNOLLY(1), p. 335.	0	0	0
25.	*C. gibbosulus* (D. H.)	Fig. 28.	0	0	0
26.	*Thia residua* HERBST	WILLIAMSON(2), p. 549.	0	0	0
27.	*Menippe mercenaria* SAY	HYMAN(4), p. 14.	0	0	0
28.	*Sphaerozius nitidus* STIMPSON	AIKAWA(2), p. 187.	0	0	0
29.	*Actumnus setifer* D. H.	Fig. 30.	0	0	0
30.	*Pilumnus hirtellus* (PENN.)	WILLIAMSON(2), p. 490. LEBOUR(3), p. 532.	0	0	0
31.	*P. spinifer* M.-EDWS.	HYMAN(4), p. 15.	0	0	0
32.	*P. villosus* HYMAN	ibid., p. 15.	0	0	0
33.	*P. minutus* D. H.	AIKAWA(1), p. 41.	0	0	0
34.	*P. vespertilio* FABR.	ibid., p. 41.	0	0	0
35.	*Heteropanope globula* D.H.	ibid., p. 40.	×	0	×
36.	*Xantho florida* (MONTAGU) = *X. incisa* LEACH	WILLIAMSON(2), p. 487. LEBOUR(3), p. 530.	0	0	0
37.	*X. hydrophilus* (HERBST)	LEBOUR(3), p. 531.	0	0	0
38.	*X. exaratus* (M.-EDWS.)	AIKAWA(1), p. 42.	0	0	0
39.	*X.* sp.	ibid., p. 43.	0	0	0
40.	*X.* sp.	WILLIAMSON(2), p. 492.	0	0	0
41.	*Panopaeus herbsti* (M.-EDWS.)	HYMAN(4), p.9.	0	0	0
42.	*Eurypanopeus derpressus* (SMITH)	ibid., p. 8.	0	0	0
43.	*Neopanope texana sayi* (SMITH)	ibid., p. 3.	0	0	0
44.	*Hexapanopeus angustifrons* RATH.	ibid., p. 10.	0	0	0
45.	*Rhithropanop. harrsi* (GOULD)	CONNOLLY(2), p. 327.	0	0	0
46.	*Laphopanop. bellus* (STIMPSON)	HART(1), p. 414.	0	0	0
47.	*Eriphia spinifrons* HERBST	HYMAN(4), p. 13.	0	0	0
48.	*Trapezia* sp.	ibid., p. 15.	0	0	0

Note 0 = presence, × = absence,

characters of the Cancroidea.

No.	2nd antenna	Telson	mxp.-chrom.		Hair Formula		
			1st mxp.	2nd mxp.	1st mx.	2nd mx.	2nd mxp.
1	B_4	A_3	—	—			
2	B_3	A	—	—			
3	B	A_2	—	—			
4	B_2	A_3	—	—			
5	B_2	A_3	—	—			
6	B_2	A_3	—	—			
7	B_2	A_3	—	—			
8	B_2	A_3	—	—			
9	B_2	A_3	—	—			
10	B_2	A_3	—	—			
11	B_4	A_3	0_2	×	6–1	2–4(6)	4–1–1
12	B_4	A_3	0_2	×	6–1	2–4(6)	5–1–1
13	B_4	A_3	—	—	6–1	3–5(8)	?
14	B_2	A_3	—	—			
15	B_2	A_2	0_2	×	6–1	2–4(6)	4–1–1
16	B_2	A_2	—	—	6–1	2–4(6)	5–1–1
17	B_4	A_1	—	—			
18	B_4	A_1	—	—	6–1	2–5(7)	3–1–1
19	B_4	A_2	×	×			
20	B_4	A_3	—	—	6–1	3–5(8)	5–1–1
21	B	A_1	0_2	0_2			
22	B_5	A_3	×	×	6–1	3–5(8)	5–1–1
23	B_5	A_2	×	×			
24	B_4	A_2	×	×	6–1	3–5(8)	5–1–1
25	B_4	A_2	—	—	6–1	3–3(6)	5–1–1
26	B_4	A_2	×	×			
27	B_2	A_2	0_2	0_2			
28	B_4	A_1	0_2	0_2	4–1	3–3(6)	5–1–0
29	A_2	A_3	—	—	6–1	3–5(8)	5–1–1
30	A_2	A_3	×	0_1	5–1	2–4(6)	?
31	A_2	A_3	—	—			
32	A_2	A_3	—	—	4–1	3–5(8)	5–1–1
33	A_1	A_3	×	0	4–1	3–5(8)	6–1–1
34	A_1	A_2	0_1	0_1			
35	A	A_3	0_1	0_1	5–1	3–5(8)	?
36	C_2	A_3	0_2	0_2			
37	C_2	A_3	0_2	0_2			
38	C_2	A_3	0_2	0_2	4–0	3–5(8)	4–1–1
39	C_2	A_3	0_2	0_2	6–1	3–5(8)	5–1–1
40	C_2	A_3	—	—			
41	C_2	A_3	0_2	0_2			
42	C_2	A_1	0b	0b	6–1	3–5(8)	?
43	C_2	A_1	0b	0b	6–1	3–5(8)	5–1–1
44	C_2	A_1	0_2	0b			
45	C_1	A_1	—	—			
46	C_2	A_1	0_2	0_2	6–1	3–5(8)	5–1–1
47	B_2	A_2	—	—	4–1	3–3(6)	4–1–0
48	B_4	A	—	—			

—=not ascertained.

the A-type of telson, and are included in *Grapsizoea*. 3 kinds of carapacial spines nearly always present, the maxillipedal chromatophores being of secondary character. They are separable into 3 groups, the 1st of which comprises the Portunidae and its allied families, the mode of serration on the endopodite of the 2nd maxilla being 2–4 (6). The Atelecyclidae and its allied families are comprised in the 2nd group, the mode of serration on the endopodite of the 2nd maxilla being usually 3–5 (8). The larvae of the Parthenopidae is placed in the 3rd group, the mode of serration on the endopodite of the 2nd maxilla being 2–5 (7).

The zoeas of the portunid group. Dorsal and rostral spines usually very long, but the lateral very short. The outer lobe of endopodite of 2nd maxilla usually smaller than the inner. Lateral knobs present on both 2nd and 3rd abdominal somites.

The characters of the portunid megalopa are, (1) there is a simple pointed rostrum, but no other spines on carapace, (2) fairly long antenna, (3) chela neither particularly large nor thick, (4) eye large, (5) coxa of last leg has a very large hook-like spine, coxae of 2nd to 3rd legs a small hook-like spine, and (6) the ischia of the 1st leg also a small hook.

Characters of the atelecyclid zoeas. Lateral spines sometimes absent. Lateral knobs on 3rd somite also sometimes either absent or all on both somites wholly disappear. Endopodite of 2nd maxilla more sharply bifurcated than that of the portunid zoeas.

Characters of the parthenopid zoeas. All kinds of carapacial spines present, laterals fairly long, compared with those of the two groups just mentioned. Lateral knobs present on both 2nd and 3rd abdominal somites. According to Lebour, the larvae of the Parthenopidae, which does not agree with those of the Majidae, is an exception to the Oxystomata, for which reason the Parthenopidae had better be regarded as an allied group of the Portunidae, or at least as a member of the Cancroidea.

(12) Family Menippidae (Table III, 27–35).

The larvae of *Menippe mercenaria*, *Actumnus setifer*, *Heteropanope globula*, *Sphaerozius nitidus*, and 6 species of G. *Pilumnus* are described. The larval characters are not uniform in the foregoing. These zoeas are separable into 2 groups, the 1st of which comprises *Menippe* and *Sphaerozius*, have the B-type of 2nd antenna and the A-type of telson, as observed in the larvae of the atelecyclid group. The

2nd group, to which belong *Pilumnus*, *Actumnus*, and *Heteropanope*, has the A-type of 2nd antenna and telson. The maxillipedal chromatophores are of secondary character in the 1st group and primary in the 2nd. The latter, which seems to retain the primitive characters, resembles the members of the Inachidae or of the Majidae, although it is distinguished from the two by the mode of serration on the endopodite of the 2nd maxilla and by the grouping of the carapacial spines. On the other hand, it is also closely related to zoeas of the Carcinoplacidae, as ORTMANN had assumed. The 1st group of the Menippidae can also be distinguished from the atelecyclid group of zoea by the mode of serration on the endopodite of the 2nd maxilla (4–1 or 5–1, but never 6–1 in the menippid zoeas) and the absence of hair on the basal joint of the endopodite of the 2nd maxilliped.

(13) Family Xanthidae (Table III, 36–40).

6 zoeas of G. *Xantho* are described. Larval characters of this family very uniform. All kinds of carapacial spines present, all fairly long. 2nd antenna C_2-type, telson A-type. Secondary chromatophores present in both maxillipedes or only in one of them. Endopodite of 2nd maxilla bifurcated, mode of serration here expressed by 3–5 (8).

(14) Family Oziidae (Table III, 41–47).

The zoeas of subfamily Panopaeinae clearly differ from those of the subfamily Eriphiinae, resembling rather those of the Xanthidae. 2nd antenna C_2-type, telson A-type. All carapacial spines present, fairly long. *Panopaeus herbstii* and *Lophopanopeus bellus* have secondary chromatophores in both maxillipedes, but *Eurypanopeus depressus* and *Neopanope texana sayi* have both primary and secondary chromotophores simultaneously in both maxillipedes. *Hexapanopeus angustifrons* has only secondary chromatophore in the 1st maxilliped, but both primary and secondary chromatophores in the 2nd maxilliped. Mode of serration on endopodite of 2nd maxilla similar to that of the Xanthidae. Zoeas of the Panopaeinae can be distinguished from those of the Xanthidae by the former having 2 kinds of chromatophores in the maxillipedes. The 2nd group, to which belongs *Eriphia spinifrons*, resembles zoeas of the 1st group of Menippidae by having the B-type of 2nd antenna and A-type of telson. All carapacial spines are also present. The zoea of *Eriphia* are scarcely distinguishable from those of the 1st group of Menippidae.

(15) Family Trapeziidae (Table III, 48).

Trapezia sp., which alone is known for its larval form, resembles

in important features those of the Menippidae (1st group) and of the Eriphiinae, all scarcely distinguishable from one another.

Upon comparing the larval features of Menippidae, Xanthidae, Oziidae, and Trapeziidae, they are separable into 3 main groups according to differences in the structure of the 2nd antenna. Telson always of A-type.

Group A. The zoeas, which have the A-type of 2nd antenna, as observed in *Pilumnus*, *Actumnus*, and *Heteropanope*, seem to retain the primitive characters. This group can be connected directly with the zoeas of Carcinoplacidae and Gonoplacidae, followed by the Grapsini.

Group B. Zoeas have the B-type of 2nd antenna. Here we have zoeas of *Sphaerozius*, *Menippe*, *Eriphia*, and *Trapezia*. This group may be related to the atelecyclid group through the zoea of the Thiidae, all being member of the large *Grapsizoea* group.

Group C. Zoeas have the C-type of antenna. Zoeas of the Xanthidae and the subfamily Panopaeinae of the Oziidae belong to this group. Group A is the most primitive and group C the most highly developed. The relationship between these groups are shown in the scheme on p. 92. Hyman noted that, when arranged in a series, the zoea of *Panopaeus* is found to be most highly specialized, while that of *Pilumnus* is least so (Hyman, 1925). Rathbun and others have placed all these genera in the family Xanthidae without dividing them into subfamilies. Neverthless, considering their larval features, there are certainly 3 clearly distinct groups among them. According to Lebour, the larvae of the Xanthidae naturally divide themselves into 3 groups, the one which belongs *Xantho*, with a rudimentary antennal scale (C_2-type), and the other, to which belong *Pilumnus*, with a well developed exopodite (A-type). Cano, in describing *Eriphia*, showed the 3rd group with antenna like the *Portunus* (B-type). Therefore, as suggested by differences in the larval features, it may be better to keep some subfamilies or families for each of them.

(16) Families Carcinoplacidae and Gonoplacidae (Table IV, 1).

The zoeas of *Gonoplax rhomboides* and *Geryon affinis* are described, although the writer is unable to refer directly to description of the latter. Both zoeas, which have the A-type of 2nd antenna and telson, seem closely related to the Menippidae (2nd group), as Ortmann assumed. They are yet distinguishable from the member of the Menippidae, seeing that they have secondary chromatophores in the maxilli-

pedes. Since the endopodite of the 2nd maxilla is bifurcated, the zoeas also differ from those of members of the Inachidae.

(17) Family Pinnotheridae (Table IV, 2–11).

The zoeas of this family are separated into 2 groups, *Pinnozoea* and *Dissodactylozoea*. *Pinnixa chaetopterana* and some zoeas of G. *Pinnotheres* which belong to *Pinnozoea*, have the D-type of 2nd antenna and F-type of telson. *Dissodactylozoea*, which comprises *Dissodactylus mellitae* and *Pinnixa sayana*, have the D-type of 2nd antenna and B-type of telson. Both *Pinnozoea* and *Dissodactylozoea* belong to the Pinnotheridae. The following are additional characteristics: (1) endopodite of 2nd maxilla single, (2) endopodite of 2nd maxilliped 1- or 2-articulate, (3) maxillipedal chromatophores generally primary in character, except *Pinnixa chaetopterana*, which has secondary maxillipedal chromatophores. Miyake (1935) divided the F-type telson into 2 subtypes, F_1- and F_2-types. The former type is peculiar to *Pinnotheres* and the latter to *Pinnixa*, the two having different telson-forks. He noted also that the zoea may be regarded as belonging to *Pinnotheres* if it has a D-type of 2nd antenna and F_1-type of telson, in which case the mode of serration on the endopodite of the 2nd maxilla and the presence or absence of carapacial spines serve to determine species in the *Pinnotheres* (Miyake, 1935, p. 201).

The zoeas raised from berried crabs are mostly Pinnozoeas, whereas Dissodactylozoeas are more frequently observed among plankton than Pinnozoeas. The writer would define the D-type of telson in the Hymenosomidae as one with a telson-fork that is smaller or at least nearly equal to the inner spines in length. There are some telson intermediate between this D-type and the B-type of the Pinnotheridae. The *Hymenozoea* of the Hymenosomidae look very much like *Dissodactylozoea* of the Pinnotheridae. Miers placed these two families in the Pinnotheridae. In other respects, *Hymenozoea* resembles the member of the Inachidae as already mentioned. The classification of these crabs must be examined again.

(18) Family Grapsidae (Table IV, 12–28).

Several larvae of this family are described. They are not uniform in larval characters, contrary to Hyman's conclusion (Hyman, 1924), and are separable into 3 groups, although this division is not in complete accord with the adult classification. The endopodite of the 2nd maxilla is always bifurcated, the mode of serration being here usually 2–2 (4) or in less frequent cases 2–3 (5) or 3–5 (8). The endopodite

Table IV. List of larval

No.	Species	Reference	Carapacial spines		
			Ros.	Dor.	Lat.
1.	*Gonoplax rhomboides* (L.)	Lebour(3), p. 534.	0	0	0
2.	*Pinnixa sayana* (Stimpson)	Hyman(2), p. 6.	0	0	0
3.	*Pinnotheres maculatus* Say	ibid., p. 5.	0	0	0
4.	*Pinnix chaetpterana* (Stimp.)	ibid., p. 5.	0	0	0
5.	*Pinnotheres veterum* Bosc	ibid., p. 3, Lebour(3), p. 537	0	0	0
6.	*P. pisum* (Pennant)	ibid., p. 4, ibid., p. 536.	0	×	0
7.	*P. ostrum* Say	ibid., p. 3.	×	×	×
8.	*P. pholothurias* Semper	ibid., p. 4.	0	0	×
9.	*P. taylori* Rathbun	Hart(1), p. 192.	×	×	×
10.	*P. latissimus* Bürger	Miyake(1), p. 192.	0	0	×
11.	*Dissodactylus mellitae* Rathbun	Hyman(2), p. 5.	0	0	0
12.	*Planes minutus* L.	Hyman(4), p. 5.	0	0	×
13.	*Pachgrapsus marmoratus* Fabr.	Williamson(2), p. 518.	0	0	×
14.	*Hemigrapsus oregoniensis* (Dana)	Hart(1), p. 430.	0	0	0
15.	*H. nudus* (Dana)	ibid., p. 424.	0	0	0
16.	*H. sanguineus* (d. H.)	Aikawa(1), p. 45.	0	0	0
17.	*H. penicillatus* (d. H.)	ibid., p. 46.	0	0	0
18.	*H. longitarsis* (Miers)	ibid., p. 45.	0	0	0
19.	*Eriocheir japonicus* d. H.	ibid., p. 47.	0	0	0
20.	*E. sinensis* M.-Edws.	Peters(1), p. 157.	0	0	0
21.	*Platygrapsus depressus* (d. H.)	Aikawa(1), p. 47, Figs. 32, 33.	0	0	×
22.	*Grapsus grapsus* L.	Fig. 31.	0	0	×
23.	*Sesarma incisa* Bosc	Hyman(4), p. 6.	0	0	×
24.	*S. reticulata* Say	ibid., p. 6.	0	0	×
25.	*S. sinerea* (Bosc)	ibid., p. 6.	0	0	×
26.	*S. picta* d. H.	Fig. 34.	0	0	×
27.	*S.* sp.	Aikawa(1), p. 48.	0	0	×
28.	*Plagusia dentipes* d. H.	Figs. 35, 36.	0	0	0
29.	*Cardisoma guanhumi* Latr.	Moreira(1), p. 155.	×	0	×
30.	*C. armatum* Herklots	Cannon(1), p. 11.	0	0	0
31.	*Macrophthalmus dilatatus* d. H.	Aikawa(1), p. 50.	0	0	×
32.	*M. depressus* Rüppell	ibid., p. 50.	0	0	×
33.	*M. japonicus* d. H.	ibid., p. 50.	0	0	×
34.	*Tympanomerus pusillus* Rathbun	ibid., p. 50.	0	0	0
35.	*Scopimera globosa* d. H.	ibid., p. 50.	0	0	0
36.	*Uca pugilator* (Bosc)	Hyman(1), p. 485.	0	0	×
37.	*U. pugnax* (Smith)	ibid., p. 485.	0	0	×
38.	*U. minax* (Le Conte)	ibid., p. 485.	0	0	×

Note: 0 = presence, × = absence,

characters of the Grapsini.

No.	2nd antenna	Telson	Mxp.-chrom.		Hair Formula		
			1st mxp.	2nd mxp.	1st mx.	2nd mx.	2nd mxp.
1	A_3	A_2	0_2	0_2			
2	D	B	×	×			
3	D	F_2	0_2	×	4–×	3	5
4	D	B	0_2	×	2–×	3	5–0
5	D	F_1	0_1	0_1			
6	D	F_1	—	—			
7	D	F_1	0_1	0_1			
8	D	F_1	×	×			
9	D	B	0_1	0_1	4–0	4	3–0
10	D	B	×	×	4–0	3	5
11	D	B	0_2	×			
12	C_2	A_1	0_1	0_1	4–1	2–2(4)	4–1–0
13	C_2	A_1	—	—	6–1	2–2(4)	?
14	B_2	B	—	—	5–1	2–2(4)	6–1–0
15	B_2	B	—	—	5–1	2–2(4)	5–1–0
16	B_2	B	0_2	0_2	5–1	2–2(4)	5–1–0
17	B_2	B	0_2	0_2	5–1	2–2(4)	5–1–0
18	B_2	B	0_2	×	6–1	3–5(8)	5–1–0
19	B_2	A_2	0_2	0_2	6–1	3–5(8)	5–1–0
20	B	B	0_2	×	?	?	5–0–0
21	B_2	B	0_2	×	5–1	2–2(4)	5–1–0
22	B_4	B	0_2	×	5–1	2–3(5)	5–1–0
23	B_4	B	—	—			
24	B_2	B	×	0_2			
25	B_4	B	0_2	0_2			
26	B_4	B	—	—	5–1	2–3(5)	6–1–0
27	B_2	B	×	0			
28	B_4	B	0_1	0_1	5–1	2–3(5)	5–1–1
29	B_3	B	—	—	4–×	2–3(5)	3–1–0
30	B_2	B	0_2	×			
31	B_1	B	0_2	0_2	5–1	2–2(4)	6–1–1
32	B_1	B	0_2	0_2	5–1	2–2(4)	6–1–1
33	B_1	B	0_2	0_2	5–1	2–2(4)	6–1–1
34	C_2	A_1	×	×	4–0	2–3(5)	5–1–0
35	C_2	A_1	×	×	4–0	2–3(5)	5–1–0
36	B_2	B	0_2	×	4–0	3	4–0–0
37	B_2	B	—	—	4–0	3	4–0–0
38	B_2	B	—	—	4–0	3	4–0–0

—= not ascertained.

of the 2nd maxilliped has 3 joints, its basal joint being hairless.

The 1st group, to which belongs *Plagusia dentipes,* has B-type of both 2nd antenna and telson. Maxillipedal chromatophores of primary character. 2nd group, to which belong most species of Grapsidae, has B-type of both 2nd antenna and telson. Maxillipedal chromatophores of secondary character. *Hemigrapsus, Platygrapsus, Eriocheir, Sesarma, Grapsus,* and *Hetergrapsus* belong to this group. Only *Heterograpsus longitarsis* shows the mode of serration 3–5 (8) on the endopodite of the 2nd maxilla, in this differing from its allied species. *Eriocheir japonicus* has the A-type of telson, and *E. sinensis* the usual B-type telson. It is rather unusual to find zoeas of the same genus having different types of telson. The 3rd group, which comprises *Planes minutus* and *Pachygrapsus,* has the C-type of 2nd antenna and A-type of telson. Maxillipedal chromatophores are of primary character. The 3rd group of *Planes* and *Pachygrapsus* is therefore the most highly developed group among the Grapsidae, as assumed in other cases.

(19) Family Gecarcinidae (Table IV, 29–30).

The zoeas of *Cardisoma guanhumi* and *C. armatum* are described. Both 2nd antenna and telson are B-type. *C. guanhumi* has dorsum alone, while *C. armatum* has all kinds of carapacial spines. Secondary chromatophore present in 1st maxilliped (*C. armatum*). Endopodite of 2nd maxilla bifurcated and mode of serration here is 2–3 (5) as seen in *Sesarma* and *Plagusia.* The zoeas of this family resemble those of the Grapsidae rather than those of the Ocypodidae.

(20) Family Ocypodidae (Table IV, 31–38).

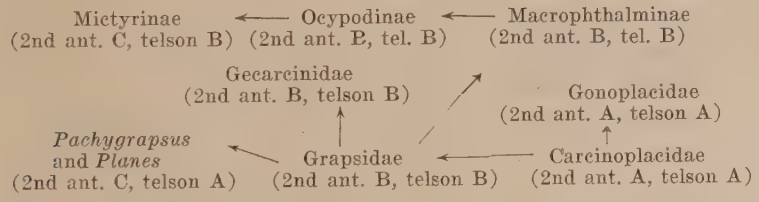
The zoeas of *Macrophthalmus, Tympanomerus, Scopimera,* and *Uca* are described. These zoeas are separable into 3 groups as in the case of their adult forms.

The 1st group, to which belongs *Macrophthalmus,* has the following characters: (1) lateral spines absent, (2) 2nd antenna B-type, (3) telson B-type, (4) secondary chromatophores in both maxillipedes, (5) endopodite of 2nd maxilla bifurcated, mode of serration 2–2 (4) as seen in the larvae of the Grapsidae, and (6) 2nd maxilliped has 3-jointed endopodite, its basal joint having a hair, differing from the joint in the Grapsidae.

The 2nd group, which comprises *Tympanomerus* and *Scopimera,* and which corresponds to the subfamily Mictyrinae, has the following characteristics: (1) all kinds of carapacial spines present, (2) 2nd

antenna C_2-type, (3) telson A_1-type, (4) no chromatophores present in maxillipedes, (5) endopodite of 2nd maxilla bifurcated, mode of serration 2–3 (5), and (6) 3rd joints of endopodite of 2nd maxilliped hairless. The larvae of the subfamily Mictyrinae are thus easily distinguishable from members of the Xanthidae, Panopaeinae, and *Planes* and *Pachygrapsus* of Grapsidae.

The 3rd group, to which belong *Uca* and *Ocypoda* of the subfamily Ocypodinae, has both 2nd antenna and telson of B-type. Lateral spines absent, maxillipedal chromatophores of secondary character, endopodite of 2nd maxilla single, with 3 hairs on tip. This member of the Ocypodinae resembles that of the Macrophthalminae (1st group). The two differ in the mode of serration on the endopodite of the 2nd maxilla and in the grouping of chromatophores in the maxillipedes. Of the Ocypodidae, the Mictyrinae is most highly developed, while the 1st group (Macropthalminae) is the most primitive. The relationship between these groups, as Ortmann had assumed, is shown in the following scheme:



Part IV. Key to families based on larval characters, and its application to undetermined zoeas

1. Key of families

A_1 2nd antenna E-type
  B_1 Telson G-type ..... **Lithozoea**
    C_1 No brown chromatophores present in body
      D_1 Enp. of 2nd mx. single ..... Dromiidae (*Dromia*)
      D_2 Enp. of 2nd mx. 2-articulate or bifurcated
        E_1 Enp. of 2nd mxp. 4-articulate .... Homolidae (*Latreillia*, *Parahomola*)
        E_2 Enp. of 2nd mxp. 5-articulate ..... Homolidae (*Homola*)
A_2 2nd antenna D-type
  B_1 Telson E-type ..... **Leucozoea**

C_1 Primary chroms. present or absent in mxpds. .....
.....Leucosiidae (*Ebalia Illia, Leucosia, Philyra*)
B_2 Telson D-type .....**Hymenozoea**
C_1 Primary chroms. in both mxpds. .....
...Hymenosomidae (*Trigonoplax, Halicarcinus, Rhynchoplax*)
B_3 Telson B-type .....**Dissodactylozoea**
C_1 Secondary chroms. absent or present in mxpds. .....
.....Pinnotheridae (*Pinnixa, Dissodactylus*)
B_4 Telson F-type .....**Pinnozoea**
C_1 Primary or secondary chroms. present or absent in mxpds. ...
.....Pinnotheridae (*Pinnotheres, Pinnixa*)
A_3 2nd antenna A-type.
B_1 Telson C-type .....**Ethusozoea**
C_1 No brown chroms. present in mxpds.
D_1 Enp. of 2nd mx. single
E_1 Enp. of 2nd mxp. 3-articulate .....Dorippidae
F_1 all kinds of carapacial spines present...*Ethusa, Dorippe*
F_2 Lateral spines absent .....*Dorippe*
B_2 Telson A-type .....**Inachizoea**
C_1 Primary chroms. present in mxpds.
D_1 Enp. of 2nd mx. single .....Inachidae
E_1 Only dorsum present .....*Stenorhynchus, Achaeus, Acanthonyx, Macropodia, Inachus*
E_2 Only lateral spines absent.....*Pleistacantha, Huenia, Pugettia*
D_2 Enp. of 2nd mx. bifurcated
E_1 2nd ant. A-type .....Menippidae
F_1 All carapacial spines present .....*Actumnus, Pilumnus*
F_2 Dorsum alone present .....*Heteropanope*
C_2 Secondary chroms. present in mxpds.
D_1 Enp. of 2nd mx. single .....Majidae
E_1 Only lateral spines absent .....*Pisa, Naxia*
E_2 All spines present .....*Herbstia*
D_2 Enp. of 2nd mx. bifurcated...Carcinoplacidae, Gonoplacidae
C_3 Primary or secondary chroms. present in mxpds.
D_1 Enp. of 2nd mx. bifurcated
E_1 2nd ant. A-type .....Periceridae
F_1 Lateral spines absent .....*Tiarinia*
F_2 Only dorsum present .....*Lissa*

A_4 2nd ant. B-type ..... **Grapsizoea**

B_1 Telson A-type

C_1 Primary chroms. in mxpds.

D_1 All carapacial spines present .....Majidae

E_1 Lateral knobs only on 2nd abdominal somite.....
.....*Maia, Eurynome*

E_2 Lateral knobs on both 2nd and 3rd somites.....
.....*Hyas, Chionecetes*

C_2 Secondary chroms. in mxpds.

D_1 Mode of serration on enp. of 2nd mx. 2–4 (6),
and lateral knobs on both 2nd and 3rd somites.....
.....Portunid group of zoeas

D_2 Mode of serration 3–5 (8), and lateral knobs on
both somites or only on 2nd or wholly absent .....
.....Atelecyclid group of zoeas

E_1 Mode of serration on enp. of 1st mx. 6–1.....
.....Atelecyclidae, Carcinidae, Cancridae

E_2 Mode of serration 4–1 or 5–1.....Oziidae, Trapeziidae

D_3 Mode of serration on enp. of 2nd mx. 3–3 (6).....
Cancridae (*Cancer*), Menippidae (*Menippe, Sphaerozius*),
Oziidae (*Eriphia*).

D_4 Mode of serration on enp. of 2nd mx. 2–5 (7).....
.....Parthenopidae

C_3 No mxpdal. chrom. present, and the mode of
serration on enp. of 2nd mx. 2–5 (7) and that on
1st mx. 4–0 .....Calappidae

B_2 Telson B-type.

C_1 Primary chroms. in mxpds.

D_1 Enp. of 2nd mx. single

E_1 All carapacial spines present...Gecarcinidae (*Cardisoma*)

E_2 Lateral spines absent .....Ocypodidae (*Uca*)

D_2 Enp. of 2nd mx. bifurcated

E_1 All carapacial spines present

F_1 Mode of serration on enp. of 2nd mx. 2–2 (4).....
.....Grapsidae (*Hemigrapsus, Heterograpsus*)

F_2 Mode of serration 3–5 (8).....
.....Grapsidae (*Hemigrapsus, Eriocheir*)

E_2 Lateral spines absent

F_1 Mode of serration on enp. of 2nd mx. 2–2 (4)

G_1 1st joint of enp. of 2nd mxp. has no hair.....
.....Grapsidae (*Platygrapsus*)
G_2 1st joint bears a hair..Ocypodidae (*Macrophthalmus*)
F_2 Mode of serration 2–3 (5).....
.....Grapsidae (*Sesarma, Grapsus*)
A_3 2nd ant. C-type ..... **Xanthozoea**
B_1 Telson A-type
C_1 Mode of serration on enp. of 2nd mx. 2–2 (4).....
.....Grapsidae (*Planes, Pachygrapsus*)
C_2 Mode of serration 3–5 (8)
D_1 Denticle on the telson-fork only 1 (A_1-type).....
.....Oziidae (*Rhithropanopeus, Eurypanopeus, Neopanope, Lophopanope, Hexapanope*)
D_2 Denticles on telson-fork 3 (A_3-type).....
.....Xanthidae (*Xantho*), Oziidae (*Panopaeus*)
C_3 Mode of serration 2–3 (5).....
.....Ocypodidae (*Tympanomerus, Scopimera*)

2. Application of this key to undetermined zoeas

(1) *Zoea pelagica* Bosc (Williamson, 1915, p. 563, fig. 516). This zoea has the E-type of telson (gegabelt oder halbmondförmig und in seinen Innern sind einige kurze Stacheln) and D-type of 2nd antenna (zweite Antennen ist einfach). It is undoubtedly a *Leucozoea*, belonging to the Leucosiidae, although Lilljeborg thought it belonged to G. *Hyas*.

(2) *Zoea* sp. J. V. Thompson (Williamson, 1915, p. 564, fig. 518). This zoea has the B-type of 2nd antenna and telson, and in addition, has 3 kinds of carapacial spines. This is a typical *Grapsizoea*, probably belonging to the Grapsidae.

(3) *Zoea* sp. H. Rathke (Williamson, 1915, p. 565, fig. 519). 2nd antenna is B-type and telson A-type. Lateral spines absent. Williamson regarded it as the zoea of *Portunus maenus*. Although the zoeas of *P. plicatus* and *Carcinus maenus* are also similar to it. It is therefore impossible to determine this zoea without referring to the hair formula and the grouping of chromatophores in the maxillipedes and in the abdomen.

(4) *Zoea* sp. Dohrn (Williamson, 1915, p. 566, fig. 521) and *Zoea boscii* Guerin-Meneville (ibid., p. 564, figs. 516). It being impossible to be certain of their features from descriptions, they have

to remain undetermined.

(5) *Zoea* sp. Claus (Williamson, 1915, p. 566, figs. 522, 523) Lateral spines absent. 2nd antenna of D-type (einfach, auf conischen Höcker reduzierte Antennen) and telson D-type (fig. 523). This undoubtedly is a *Dissodactylozoea*, belonging to the family Pinnotheridae.

(6) Xanthid zoea (Lebour, 1934, p. 15, fig. 13) Lebour regarded it as a member of the Xanthidae, resembling greatly the latter, except the absence of the lateral spines. The telson of this zoea is clearly of B-type (fig. 13, 1). In the Xanthidae, zoeas with B-type of telson are members of the Menippidae, or Eriphiinae, or Trapeziidae, although they all have all kinds of carapacial spines. The writer therefore regards the Xanthid zoea of Lebour as a member of the Grapsidae, especially the allied form of G. *Pachygrapsus*, although this cannot be said with certainty as the mode of serration on the endopodites of both 1st and 2nd maxillae and of the 2nd maxilliped are not known.

(7) Brachyura, incertae sedis (Gurney, 1924, fig. 78). This zoea has the D-type of both 2nd antenna and telson. Rostral spine alone present. Hair formula 4–1, 4, ?. This is certainly a *Hymenozoea* and belongs to the Hymenosomidae.

(8) *Inachizoea* (Aikawa, 1933, figs. 1–4, 30). The zoea with the A-type of 2nd antenna and telson is an *Inachizoea*, and found only rather rarely among plankton. *Inachizoea genkaiensis* (fig. 1), *I. bidentata* (fig. 2), and *I. punctata* (fig. 4) are members of the 2nd group of Inachidae, which comprises *Huenia*, *Pugettia*, and *Pleistacantha*. Although *I. minuta* (fig. 3) and *I. macrosphaera* (fig. 30) have features similar to the Inachidae, both differ from the latter, since the rostral spine alone is present. These two zoeas may belong the unknown group of Inachidae.

(9) *Grapsizoea* (Aikawa, 1933, fig. 5–38). Grapsizoeas are always provided with the B-type of 2nd antenna, of which those with the A-type of telson are very difficult to determine so far as our present knowledge goes. In the matter of hair formula and the character of maxillipedal chromatophores, the writer has determined some of them as follows:

I. Members of the Majidae.
Grapsizoea tusimaensis (fig. 6), *G. hukuiensis* (fig. 8), *G. sagamiensis* (fig. 12), *G. sphaerophthalma* (fig. 13), *G. regularis* (fig. 18), *G. otawaensis* (fig. 30) and *G. bucephalis* (fig. 30).

II. Members of the Portunid group.

G. toyamaensis (fig. 9), *G. aomoriensis* (fig. 10), *G. akitaensis* (fig. 11), *G. pelagica* (fig. 30), *G. elegans* (fig. 31), and *G. sumatraensis* (fig. 32).

III. Members of the Atelecyclid group.
G. hukuokaensis (fig. 7), *G. macrophthalma* (fig. 15), and *G. spinifera* (fig. 17).

IV. Members of the Grapsidae.
G. globosa (fig. 5), *G. longicauda* (fig. 14), *G. longifurca* (fig. 19), *G. serrata* (fig. 25), *G. latifrons* (fig. 27), *G. orbitalis* (fig. 28), and *G. tropica* (fig. 32).

V. Members of the Trapeziidae or Eriphiinae or Menippidae.
G. japonica (fig. 16).

IV. Members of the Macrophthalminae.
G. brevispinosa (fig. 26).

Grapsizoea mysis (fig. 16), *G. acutirostrata* (fig. 23), *G. manazuruensis* (fig. 24), and *G. misakiensis* (fig. 31) have not yet been determined.

(10) *Xanthozoea* (Aikawa, 1933, figs. 33–38). The zoeas with C-type of 2nd antenna is Xanthozoea: it is determined more easily than Grapsizoea.

I. Members of the Xanthidae or Panopaeinae (Oziidae).
Xanthozoea pilumniformis (fig. 35) and *X. tropica* (fig. 38).

II. Members of the Mictyrinae (Ocypodidae).
X. lakutoensis (fig. 33), *X. ocypoda* (fig. 36), *X. elongata* (fig. 38).

III. Members of the Grapsidae (allied form to *Pachygrapsus*).
X. longiclavata (fig. 37).

Xanthozoea hyalina, yet undetermined.

(11) *Dissodactylozoea* (Aikawa, 1933, figs. 39–44). *Dissodactylozoea* is a member of the Pinnotheridae, and has the D-type of 2nd antenna and B-type of telson. More *Pinnozoea* of the Pinnotheridae is obtained by rearing berried crabs than *Dissodatylozoea*, while in contrast to it, the former is found less among plankton than the latter. In most Dissodactylozoeas, it is impossible to determine the species or even the genera to which they belong.

(12) *Ethusozoea* (Aikawa, 1933, figs. 45, 46) *Ethusozoea* has A-type of 2nd antenna and C-type of telson. *Ethusozoea lineata* may belong to G. *Dorippe*, the lateral spines being absent. *E. koreana* may belong to G. *Ethusa*, all kinds of carapacial spines being present.

(13) *Hymenozoea* (AIKAWA, 1933, figs. 47, 48). This group of zoea, which is a member of the family Hymenosomidae, is provided with D-type of both 2nd antenna and telson.

(14) *Leucozoea* (AIKAWA, 1933, figs. 40–56). *Leucozoea*, with D-type of 2nd antenna and E-type of telson, is a member of the family Leucosiidae.

(15) *Lithozoea* (AIKAWA, 1933, figs. 58–60). It is a question whether the Lithozoea is always a member of both Dromiidae and Homolidae or not. They can be determined with safety after the larvae of the families Albuneidae, Hippidae and their allied groups have been carefully studied. The larva of the Raninidae may be comprised in this group. *Lithozoea kagosimaensis* (fig. 58) and *L. multispinosa* (fig. 59) are not yet determined. *L. serrulata* (fig. 60) may belong to the Homolidae, especially to G. *Homola*.

(16) *Pinnozoea* (AIKAWA, 1933, fig. 57). S. MIYAKE (1935) regarded *Pinnozoea ostrea* as the zoea of *Pinnotheres latissimus* BÜRGER.

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